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INTERRELATIONSHIP OF IN-SITU ROCK PROPERTIES,
EXCAVATION METHOD, AND MUCK

H. F. Haller, et al

Holmes and Narver, Incorporated

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INTERRELATIONSHIP OF IN-SITU ROCK PROPERTIES, EXCAVATION METHOD, AND MUCK CHARACTERISTICS

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February 16, 1972 - August 31, 1972

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13. ABSTRACT Reports results of research to correlate the properties of in-situ rocks with materials handling properties of muck and parameters of excavation systems. Goals are to develop methods for predicting muck characteristics from collected data and for selection of transport equipment through the Muck Designation Number concept. Muck sample, rock, and operating data collection, testing methods, data processing, development of MDN's, preliminary regression analyses, and equipment selection are described.		
 Data available 8/31/72 from 50 samples at 23 sites (16 samples from 8 sites in 1972) is presented in raw data printout and narrative-graphic summary form, showing lithology, rock properties, operating data, and muck properties. Tentative MDN's are described by composite size and distribution curves, with preliminary regression analyses of 27 data sets and prediction accuracies of over 90 percent. Applications to equipment selection/design include input for design formulae used in mathematical models of belt and hydraulic conveying systems.		
 DOD implications include more rational transport equipment selection and design, with resultant speed and cost benefits. Recommended additional research includes sampling operations and formations not previously available, resampling to improve the confidence level of the data, dynamic testing for coefficients of rock strength in addition to current tests, and predictor refinements.		

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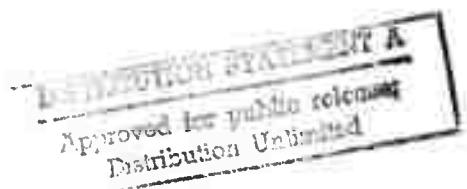
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INTERRELATIONSHIP OF IN-SITU ROCK PROPERTIES, EXCAVATION METHOD, AND MUCK CHARACTERISTICS

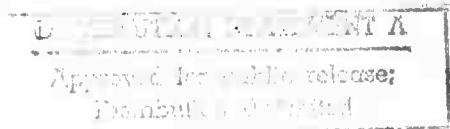
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FOREWORD

This report presents the results of research performed during 1971 and 1972 into the interrelationships of in-situ rock properties and the characteristics of muck produced by various excavation methods. The authors wish to express their appreciation and that of Holmes & Narver, Inc., for the assistance provided by the many U. S. Bureau of Mines and Holmes & Narver staff members, as well as those individuals and organizations listed below who also participated in the program.

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INTRODUCTION AND SUMMARY

PURPOSE

The purpose of the program is to develop a method for predicting the materials handling properties of muck from the engineering properties of rock and the parameters of excavation systems, and a means of selecting the most suitable transportation equipment for the muck through the concept of Muck Designation Numbers (MDN's).

MDN's range in whole numbers from 1 through 7. MDN 1 describes muck with a large maximum piece size, more than 5 percent plus 6-inch material, and a predominant distribution in the plus 1/2-inch size range. The maximum size of MDN 7 is relatively small, the predominant distribution is minus 1/2 inch, and more than 20 percent is minus 200 mesh in size. Intermediate numbers range in size and size distribution between end points. The concept recognizes that muck characteristics vary with excavation methods as well as rock properties.

SCOPE

This report describes results of research performed in the first half of a contract initiated on February 16, 1972, for a 14-month period. The work is a continuation of a previous 12-month contract of which the results also are covered to summarize the total accomplished and the current status of the program.

CONCLUSIONS

Program activities have included sample and data collection, physical testing, data storage and processing, development of tentative MDN's, preliminary correlation with rock properties, and establishing the parameters of muck handling systems.

Regression analysis of seventeen sets of rock property, Raise Boring Machine (RBM), and Tunnel Boring Machine (TBM) data produced a predictor equation with an apparent accuracy over 90 percent. Analysis of 10 sets of rock data with conventional excavation parameters produced an accuracy of nearly 100 percent. Inclusion of additional data is expected to improve prediction reliability.

Predictor accuracy probably will not be maintained at preliminary levels, and appropriate parameters remain to be developed for shield and drag cutter TBM's. However, it can be concluded that MDN's are predictable within the limits of reasonable accuracy for the majority of rocks and methods sampled under the program.

Preliminary analysis also shows that MDN data can be used as input for design formulae and performance-cost models of belt and hydraulic conveying systems.

REFERENCE TO DETAILS

Details of the topics summarized below are arranged under the same headings in the report.

SUMMARY

1. Technical Problems

Inadequate subsurface information on new tunnels limits the effectiveness of construction planning and forces contractors to base bids on methods and equipment which may not suit the job. Loss of time, lives, and money has often resulted.

Estimates of the volume of tunnel construction made several years ago focused attention on the importance of a more logical approach to methods and equipment selection. The advisability of increasing excavation speed while reducing costs has been reemphasized by recent studies which show that prior tunneling forecasts were conservative.

Muck transportation obviously is a major factor in tunnel cost; improvements would reduce tunnel costs significantly. Knowledge of the basic properties of a material is fundamental to improvement of handling techniques. Prior to the inception of the MDN program, however, practically no information had been collected on muck characteristics; and correlations between muck properties, the properties of the in situ rock, and the components of rapid excavation systems had not been established. These data are essential as a basis for optimum selection from the transportation systems in current use and for development of the high speed systems required in the future.

2. General Methodology

The research plan is to collect muck samples, lithologic and operating data, and rock specimens, where necessary, from operating tunnels; determine muck characteristics and rock properties by physical testing; correlate and analyze rock and muck properties and quantify relationships through MDN's; and correlate rock and muck characteristics, MDN's, and the components of rapid excavation systems with muck transport system capabilities.

Lithologic data consists of descriptions of rocks, their classification by probable origin and subsequent alteration, and Rock Quality Designations (RQD's) which indicate the frequency of discontinuities. Operating data includes descriptions of the equipment and methods used in the total excavation system. Rock test data includes unconfined uniaxial compressive strength, dry unit weight, hardness, and stress-strain relationships known as Young's modulus and Poisson's ratio. Commercial muck test data includes size distribution, shape, moisture content, dry loose unit weight, and abrasiveness. Additional muck tests by the Pittsburgh Mining and Safety Research Center (PMSRC) determine Atterberg Limits, potential volume change, specific gravity, angles of repose, slide, and internal friction, apparent cohesion, and bulk density.

3. Technical Results

3.1 Site Selection

A list of current and scheduled tunnels, originally compiled to assure that program objectives could be met, has been revised periodically. The current list is included in Appendix A. Sites for data and sample collection were selected with emphasis on mechanical operations in hard rock. In the first year, some soft rock and conventional tunnels were included as examples of unusual advance rates and systems. In the current program, conventional operations in hard rock at deep mines have been sampled at client request.

3.2 Sample and Data Collection

In the current program, operating data and sixteen muck samples were collected from eight sites. Totals for the program are 50 samples from 23 sites. Resampling at four sites confirmed the reliability of initial results. All other samples reflect differing lithologies, operating methods, or equipment.

Rock specimens for engineering property tests have been collected from 39 formations at 21 sites. Nineteen of the specimens, some of which represent formations sampled in 1971, were collected from nine sites in 1972.

Two shield, two RBM, 18 conventional, and 28 TBM operations have been sampled to date. Rock types sampled include four classified as Very High Strength, 20 High Strength, four Medium, 20 Low, and six Very Low Strength. Those remaining to be tested are expected to include three High Strength, six Medium, and two Low Strength classifications. A basis for these classifications follows in the body of the report.

3.3 Physical Testing

Standard tests, approved by the American Society for Testing Materials and/or the U. S. Bureau of Mines, were selected for use by commercial laboratories to ensure consistency of results.

Contracts to perform muck tests were negotiated with 18 commercial laboratories. Samples were delivered for testing and shipment of fractions to the U. S. Bureau of Mines, PMSRC, for additional tests. Under the current contract, the volume of the fractions has been increased from 2 to 4 cubic feet. At the end of the reporting period, muck tests by commercial laboratories had been reported on 46 sets of samples and on 41 sets by the PMSRC.

Contracts to perform rock tests have been negotiated with five commercial laboratories. One laboratory is now performing all rock tests. Of the 39 sets of rock specimens which have been collected, 31 test suites have been completed. Stress-strain data from testing initiated in 1972 was obtained on 11 rocks, including four sampled in 1971. Results from Schmidt hardness tests on rock cores, also initiated in 1972, have not been consistent. Modification of test methods is contemplated. Initial abrasiveness tests are planned for the third quarter of the contract.

3.4 Data Processing

Formats were developed for storage and printout of lithologic rock, muck, and tunnel data: data received to date has been stored on punch cards and printouts of these data are included as Appendix B. A form was developed for narrative and graphic presentation of data. These "System Data Sheets" are included as Appendix C.

3.5 Development of MDN's

Size distribution curves from initial sampling varied distinctly, generally as had been expected; and an algorithm to correlate MDN's, in situ rock properties, and excavation methods was developed, as described in Appendix D.

Continued sample testing produced some curves which fit well with the initial curves, and others which required establishing additional categories. Using the data available at the end of the first year, curves of similar form were plotted together, and preliminary MDN's were assigned. The resulting composite curves are shown in Figures 3-3 through 3-11.

Initial regression analyses produced the predictor equations described in the "Conclusions" section, indicating accuracies over 90 percent for RBM/TBM and for conventional operations. Computer input data are shown in Section 3, and the output tabulations are shown as Figures 3-1 and 3-2.

Additional iterations will be performed when the data collected in 1972 is in final form. Values for Young's modulus, Poisson's ratio, and Schmidt hardness resulting from current tests will be substituted for the less important parameters and inferred values used in current analyses. Current efforts to obtain data on net torque for TBM's and RBM's, and to develop operating parameters for drag cutter TBM and shield operations will be continued.

3.6 Transport System Selection

A list of equipment capabilities, system constraints, and MDN applications, prepared for the Annual Technical Report for the first year, has been included as Appendix E.

Belt and hydraulic conveying system design parameters and available parametric mathematical models of these systems were studied under the current program. Collected muck property data is appropriate as input to design formulae and the models. Some clarification of design parameters and refinement of the models is planned for the second half of the current program. An example of MDN data use in design of an hydraulic system is in progress; a comparison between an existing installation and a belt conveyor design based on MDN data, and examples of MDN applications to other systems are planned.

4. DOD Implications

Data accumulated under the program are nonexistent elsewhere in rapid excavation technology and can provide a more rational basis for selection of materials handling systems for excavation methods in current use. These data will also be invaluable to the design of the equipment required to match the improved advance rates resulting from current excavation research. As alternatives to design of systems to handle a specific type of muck, MDN data can be used to select process equipment to change muck characteristics to suit a system, or to select separation and supplementary haulage equipment for the oversize fraction of muck which cannot be handled by a continuous system which is otherwise well adapted to a site.

The MDN program provides basic data required for a rational engineering approach to problem solutions in a most important subsystem of the rapid excavation process. It will show examples of data application and should be used to indicate the areas in which research and development of modifications or new methods would be most productive.

5. Implications for Further Research

5.1 Sample and Data Collection

Recommendations for further research are based in part on the following projection of formations and excavation systems for which data is expected to be available at the end of the current contract.

Excavation Method	Rock Strength					
	Very High	High	Medium	Low	Very Low	Total
Conventional	3	9	5	1	1	19
Shield	0	0	0	0	2	2
Machine						
Drag Cutters	0	1	1	2	1	5
Disc Cutters	2	7	5	1	0	15
Roller Cutters	0	4	1	0	0	5
Combination Cutters	0	3	1	1	2	7

To be consistent with good sampling and testing practice, data reliability should be confirmed by repetition of all single samples. Eleven sites previously sampled once are expected to be available in 1973. Statistically, the number of samples used in development of a predictor equation should be greater than the number of variables in the analysis. To improve prediction reliability additional samples, detailed in the body of the report, should be collected from all types of TBM's in selected formations.

To demonstrate variations in muck characteristics with rock properties, conventional and selected TBM samples should be collected from the Medium and Low Strength rocks.

To provide data on the full range of rock types, stratified volcanic and fine grained igneous rocks should be sampled. Sampling muck from tests of unusual rock breaking techniques which may become the standards of the future should be initiated to provide data on the muck for which transport systems will be required.

5.2 Physical Testing

Continued development of testing methods to provide consistent results from Schmidt hardness tests is recommended because of the speed, low cost, and nondestructive nature of the only test for a dynamic rock property in current use.

Investigation of the Protodyakonov test for resistance to fragmentation is recommended to determine the effect of a second dynamic property on prediction accuracy.

5.3 General

Potential improvements in systems components which require the application of techniques which are technically sound but not yet developed to a point of practical application may appear in the collection and analysis of program data. These should be identified as attractive areas for research and development.

6. Special Comments

A Schmidt impact rock test hammer and two self rescuers were purchased during the reporting period for use in the program. No invention has been made in the course of the work performed under this contract.

1. TECHNICAL PROBLEMS

The effectiveness of planning for new tunnels has been limited by the quantity and quality of information concerning subsurface conditions which has been available. Owners and owner-agencies often have been reluctant to collect data on the properties of materials to be excavated, or to publish information which has been collected. Interested contractors are forced to base proposals on inadequate information about conditions to be encountered, and to base cost estimates on methods and equipment which may not be well suited for conditions as they exist. Generally, significant allowances are made both for contingencies which can be anticipated and for those which cannot be foreseen.

The importance of a more logical approach to selection of methods and equipment for tunneling became apparent when the volume of this work probable in the future was estimated several years ago; it has been reemphasized by more recent studies which indicate that prior estimates were conservative. Wider application of tunnel boring machines, which require rock property data for design, and of an engineering approach to ground support have influenced owner and agency policies to the extent that collection and dissemination of more and better quality exploratory information appears to be a current trend.

Progress has been made and is continuing in research to determine relationships between rock properties, drillability, excavation, and support requirements. Prior to inception of the program described in this report, practically no information had been collected on the characteristics of the muck produced by various excavation methods, and correlations between the engineering properties of rock, muck characteristics, and the components of excavation systems had not been established.

In the absence of muck characteristic data, an adequate basis for selection of optimum transportation methods and equipment does not exist, and tunneling progress and cost have been affected adversely. Muck data are also basic requirements for engineering the improvements to existing transport systems and the development of the new systems which will be necessary to keep pace with the higher rates of excavation predicted for the future.

2. GENERAL METHODOLOGY

Objectives of the program are to develop a method for predicting materials handling properties of muck from the in-situ properties of rock and a means of selecting the most suitable transportation equipment for muck produced by various excavation systems. The major emphasis is on mechanical excavation of hard rock. However, some soft rock and conventional operations are included as examples of unusual advance rates, equipment, and operating methods.

The program plan is to collect muck samples and operating data from tunnels and mining projects in rock of known properties; collect specimens from sites where the in-situ properties are unknown; determine muck characteristics and rock properties by physical testing; correlate and analyze rock and muck properties and quantify relationships through the concept of Muck Designation Numbers (MDN's); and to establish correlations between rock and muck characteristics, MDN's, the components of rapid excavation systems, and selection of muck transport equipment.

3. TECHNICAL RESULTS

3.1 SITE SELECTION

A list of operating and scheduled tunnels, prepared originally to assure that program objectives could be met, has been revised periodically. The latest revision is included as Appendix A. Six of the tunnels listed are expected to be completed in 1972. Letter inquiries inviting program participation by off-continent tunnel operators met with no response. These tunnels have been deleted from the list.

Tunnel contractors, although under no obligation to participate in the program, have been most cooperative. Operating mine cooperation has been equally good, although access usually requires more operator support, and the impact of economic conditions has reduced emphasis on research. Scheduling sampling and data collection on a strictly noninterference basis and full observance of safety requirements have been important in gaining operator acceptance.

Early planning assumed that one basis for site selection would be the availability of rock property data at specific sites. Experience proved that collection of these data is necessary from the majority of locations, and the program was modified to reflect this requirement.

In the first half of 1971, it became apparent that sampling tunnel operations in a wide range of rock strengths and excavation techniques would be necessary to demonstrate that muck characteristics vary distinctively with rock characteristics and operating methods. The program plan was modified to provide for data collection in the variety possible within the limits of time and availability, and additional funds were provided by contract modification to enlarge the scope of field sampling.

In the first year of the program, sites were selected to provide one-third of the samples from conventional excavation. In the current year seven conventional and nine mechanical operations have been sampled, and one more of each is expected in the second half of the year.

In response to a client request to obtain samples and data from conventional operations in strong rocks at maximum depth during 1972, sites were selected for field work in two quartzites at 7,094 feet and

6,110 feet, a phyllite at 6,200 feet, a quartz monzonite at 2,075 feet, a conglomerate at 3,960 feet, and a graywacke at 3,480 feet below the surface. At some sites, planned sampling of stronger rocks and/or at greater depths could not be accomplished because of site conditions.

3.2 SAMPLE AND DATA COLLECTION

Muck samples and operating data have been collected from 23 mine and tunnel sites. Of 50 samples, 11 were collected from sites visited only once. Resampling was done in similar formations at four sites to confirm the reliability of initial results. All other samples reflect differing lithologies, operating methods, or equipment.

The scope of collecting in-situ rock data has been greater than was anticipated originally, because formations encountered in most locations could not be correlated with the existing rock data. Rock specimens or cores have been collected for engineering property tests from 39 formations at 21 sites.

Two shield operations, two RBM, 18 conventional, and 28 TBM operations have been sampled to date. Rock types classified include four Very High, twenty High Strength, four Medium, five Low, and six Very Low Strength. Rocks which remain to be tested are expected to include three High Strength, six Medium, and two Low Strength classifications.

Nine of the sampled sites are no longer available for field work. Of the remaining sites, one is expected to complete excavation in October of 1972.

Early in the 1972 program a request was received from the Project Officer to increase the volume of samples provided for testing at the Pittsburgh Mining and Safety Research Center (PMSRC) from 2 to 4 cubic feet. Sampling and laboratory procedures were modified to comply with this request.

Muck samples collected are representative of the material as it reaches the transportation system. Muck produced mechanically normally is sampled as it leaves the conveyor which is integral with the machine. Conventional muck is sampled by channeling. Pieces which are too large for practical delivery to a laboratory are measured, and calculated weights in the various size ranges are added to adjust the screen test results. Rock specimens, or rock cores when available, are collected in sizes large enough to permit the preparation of six test specimens approximately 2-1/8 inches in diameter by 4-1/4 inches long.

Operating data in the first year of the program was collected in sufficient detail to permit inclusion of all of the components of the tunneling system in the analysis and selection of optimum transportation subsystems for specific MDN's and tunnel configurations. Experience in data analysis has indicated a need for more precise thrust, torque, and cutter data than was expected to be required for mechanical tunneling. In the current year, these data are being collected for most of the TBM operations sampled to date.

3.3 PHYSICAL TESTING

Published test methods were reviewed in detail to ensure that tests performed by commercial laboratories would yield consistent results. The following American Society for Testing and Materials (ASTM) standard methods were selected as specifications in the first year of the program.

- C566-67: Total Moisture Content by Drying
- C136-67: Sieve or Screen Analysis of Fine and Coarse Aggregates
- C117-69: Materials Finer than No. 200 Sieve in Mineral Aggregates by Washing
- C29-69: Unit Weight of Aggregate, Loose Weight Determination
- C170-50: Compressive Strength of Natural Building Stone

Specifications for the last test procedure were modified to provide for greater accuracy in specimen preparation so that results will be comparable to those reported by other rock property research programs.

Review of the data collected in the first year led to a decision to test rock specimens for deformation moduli in the current program to provide additional data for regression analyses. Following a review of test methods, ASTM Standard C170-50 was replaced by the following procedure, and additional standards were developed to conform with the practices followed by U. S. Bureau of Mines research centers in measuring strains.

- D2938-71: Unconfined Compressive Strength of Rock Core Specimens

Results of hardness tests by the Shore scleroscope, a laboratory instrument which tests hardness by rebound, are available for only three of the rock formations sampled. Additional tests by this method were found to be beyond the scope of this study. Hardness testing by the Schmidt hammer, a portable device which also tests rebound hardness, is nondestructive and relatively inexpensive and was specified for inclusion in the 1972 program. A hammer was purchased for use in testing tunnel walls and rock specimens.

Standard methods of testing abrasiveness were reviewed to determine the feasibility of collecting these data from tests on muck samples. The standard ASTM tests were found to measure the resistance of the sample to abrasion, rather than the abrasive effect on other materials. The latter is the property of greater interest in materials handling, and a machine designed for such testing was located by the Project Officer at the PMSRC and will be available to the program in the second half of the current contract period.

Modification of the standard test procedure was found necessary in testing muck from some low strength rocks. Screen testing the samples in the natural state was performed prior to the standard tests to avoid distortion of the curves caused by the disintegration of material during the wash screening which normally precedes dry sieve analysis. Natural screen test results are identified and shown as dotted lines on the size distribution curves.

Contracts to perform muck tests have been negotiated with 18 commercial testing laboratories. Collected samples were delivered for testing and shipment of minus 2-inch fractions to the U. S. Bureau of Mines, PMSRC, for additional tests to be performed at this facility. At the end of the reporting period, tests by commercial laboratories had been reported on 46 sets and by the PMSRC on 41 sets of muck samples. One set of samples tested commercially was lost in transit to the PMSRC.

Contracts to perform tests on rock specimens have been negotiated with five commercial laboratories. One laboratory is now performing all rock tests, which assures uniformity of results, but also delays some tests when the volume of work is high. Two sets of specimens destroyed in preparation for testing in 1971 were replaced in 1972. A total of 39 sets of rock specimens have been collected, on which 31 reports have been received, and 8 sets remain to be tested. Stress-strain data was obtained on 11 rocks, including 4 collected in the 1971 program. Specimens yet to be tested appear to be of the necessary quality for stress-strain testing.

Initial Schmidt hardness tests by project personnel on walls of tunnels gave results which correlated well with those reported by other researchers on similar rocks. Initial tests on 11 core specimens showed no obvious correlation with field tests or with values obtained from the hardness-compressive strength relationships established by previous investigations. Further trials on hand lapped core specimens and a modified cradle indicated that lapping raised test values somewhat nearer those observed in tunnel wall tests. Some variation in values appears to be associated with core straightness. The cost and results of testing polished flat surfaces is being investigated.

3.4 DATA PROCESSING

A format was developed for computer printout of lithologic, rock, muck, and tunnel data. Test results received to date have been stored on punch cards. Printouts of these raw data are included as Appendix B. Blank spaces on the printout indicate that data is not available on the date of the report.

Narrative and graphic summaries were prepared to combine these data with descriptions of the excavation systems from which rock and muck samples were taken, and are included as Appendix C. Rock strength classifications are based on uniaxial compressive strength, and conform with those proposed by D. U. Deere, et al., in the "Engineering Classification and Index Properties for Intact Rock," University of Illinois, 1966. These classifications are:

Very High Strength	-	Greater than 32,000 psi
High Strength	-	16,000 - 32,000 psi
Medium Strength	-	8,000 - 16,000 psi
Low Strength	-	4,000 - 8,000 psi
Very Low Strength	-	Less than 4,000 psi

Grain size classifications of igneous rocks, from A. Johannsen's "A Descriptive Petrology of Igneous Rocks," 1951, are used as follows:

Very Coarse	-	Above 3 cm
Coarse	-	1 to 3 cm
Medium	-	1 to 10 mm
Fine	-	Below 1 mm

From J. F. Kemp's "A Handbook of Rocks," 1950, sedimentary rocks of fragmental grains above 2 mm, are classified as conglomerates, while those below 2 mm in size are classified as sandstones or siltstones.

Symbols used to describe the shape of particles in the sample fractions between screen sizes are the following:

A - Angular	S - Subangular
P - Platy	R - Rounded
E - Elongated	C - Cubic
I - Irregular	Sp - Spheroid

The curves show the percentage of the total sample weight passing one screen size and retained on the next. Screen sizes below 1/2 inch were selected to provide openings which become progressively smaller by approximately 50 percent as shown below:

Screen Size	#4	#8	#16	#30	#50	#100	#200
Nominal Square Openings, Inches	0.187	0.094	0.047	0.023	0.012	0.006	0.003

The abbreviation NA is used to indicate that an item of data is not available.

3.5 DEVELOPMENT OF MDN'S

In accordance with the program plan, which provided for placing major emphasis on data collection during the first year, analysis of data and development of MDN's has been preliminary. As data first became available, test results were reviewed to confirm the validity of the conceptual classification criteria. Based on a plan of classification by materials handling characteristics, the proposed designation system employed seven numbered categories in which to group excavation products by size and size distribution. Numbers were assigned in a progression from No. 1 for muck with a relatively large maximum piece size and a predominant distribution in the 1 inch to 200 mesh range to No. 7, in which the maximum size is relatively small and the predominant distribution is in the minus 50 mesh sizes. The concept also recognized that muck characteristics would vary with the excavation method and contemplated modifying the MDN's to distinguish between excavation techniques.

Initial field work was scheduled at sites where rock strengths varied over a wide range and which would provide examples of shield, machine, and conventional operations. The size distribution curves of the muck from these sites (Identification Numbers H-1, 5-1, CL-1, NAST-1, and SF-1, Appendix C), varied distinctly, in general accordance with the

criteria, except that the size range of the predominant distribution was somewhat higher than had been inferred.

Using the initial data as a guide, a preliminary algorithm was developed for data analysis to correlate MDN's, in-situ rock properties, and excavation methods. The quantitative relationship sought was a predictor equation, obtained by multiple regression of the physical property data obtained from the rock sample tests and a predictor equation for the MDN. A discussion of this technique is included as Appendix D.

During algorithm development, resampling at four of the original sites confirmed the distinctive shape of the size distribution curves. Sampling at other sites produced some curves which fit well into the original categories and others which were distinctive enough to suggest establishing additional categories. Using the data available at the end of the first year, curves of similar form were plotted together, and tentative designation numbers were assigned. The resultant composites are shown as Figures 3-3 through 3-11.

The "T" prefix was added to all MDN's to indicate the preliminary nature of the assignments. Parameters available for the analysis of all samples included values of uniaxial compressive strength (f_c), rock quality designation (RQD), and dry unit weight (DUW) for which quantitative values were determined by field observation and testing. To avoid reducing data derivatives to extremely small values, rocks with compressive strengths of 1K psi or less have been assigned arbitrary strengths of 1. Rock classifications by origin were quantified as igneous = 1, metamorphic = 2, and sedimentary = 3; and ground water occurrence was quantified as dry = 1, minor = 2, and wet = 3. The order and magnitude of the number assignment is immaterial since these are modified in the analysis in nearly any case. Schmidt hardness values (H) are converted Shore values, where available, or inferred from data published by D. U. Deere, et al., in the "Engineering Classification and Index Properties for Intact Rock" referenced above.

Cutter spacing (CS) appeared to be an important TBM characteristic. Average dimensions were available for disc cutter and some drag cutter machines. For roller cutters for which no kerf pattern is apparent, values were obtained by dividing the body spacing by the number of buttons adjacent to a line along the face of the cutter and parallel to the axis of rotation. No kerf spacing was available for Alpine and Atlas-Copco TBM's. Net thrust values per square foot of face area (T) were available for TBM's with the same exceptions.

No appropriate operating parameters were available for the Alpine and Atlas-Copco machines or for the shield operations sampled, and the number of observations was insufficient to warrant analysis as a special case.

Parameters peculiar to conventional operations, face area per drill hole (A/H), and explosives per cubic yard excavated (PF) were calculated from collected data.

An initial analysis using rock properties alone led to a predictor equation for which the accuracy, described by the multiple correlation coefficient, was 72 percent. This was expected since operating parameters were not included. Seventeen sets of data were analyzed for machine operations using the values tabulated below:

DATA FOR ANALYSIS, MACHINE OPERATIONS										
Column		1	2	3	4	5	6	7	8	9
Ident. No.	Obs. No.	MDN	Class	f _c	RQD	D UW	H	GW	CS	T
5-1	1	2	3	22	92	166	49	1	0.20	3.56
7-2	2	2	3	22	92	166	49	1	0.20	2.91
LAW-2	3	3	3	19	100	160	42	1	0.20	4.28
LAW-3	4	3	3	19	100	160	42	1	0.20	4.28
LAW-4	5	3	3	19	100	160	42	1	0.20	3.76
MIL-1	6	4	3	36	85	166	50	2	0.16	6.09
MIL-2	7	4	3	36	85	166	50	2	0.18	6.09
QL-1	8	4	2	11	30	165	37	2	0.18	3.53
CL-1	9	5	2	9	10	174	45	2	0.09	5.09
NAST-2	10	5	1	18	90	167	55	2	0.09	3.89
NAST-4	11	5	1	24	90	160	55	2	0.09	8.45
LK-5	12	5	1	32	92	165	55	1	0.24	4.46
LK-6	13	5	1	7	86	137	50	1	0.13	17.20
NAST-1	14	5	1	18	90	167	55	2	0.09	3.89
LAY-1	15	6	3	10	84	150	47	1	0.24	2.73
NAV-1	16	6	3	2	70	142	25	1	0.30	1.31
NAV-2	17	7	3	1	60	117	25	1	0.30	0.37

Results of stepwise regression, as shown in detail on Figure 3-1, following, indicate an accuracy of slightly more than 90 percent with a standard error of 0.8360 and the listed residuals.

MULTIPLE CORRELATION COEFFICIENT..... 0.9081
 F FOR ANALYSIS OF VAR. (D.F. = 8, 8) 4.7026
 STANDARD ERROR OF ESTIMATE..... 0.8360

VARIABLE	REG. COEFF.	STD. ERR-COEFF.	COMPUTED T
5	-6.89554E-02	3.55858E-02	-1.93772
7	2.29717	1.14621	2.00414
2	-.469846	.381356	-1.23204
8	17.7298	11.4412	1.54964
3	-6.63157E-02	5.89690E-02	-1.12459
6	.104435	6.65627E-02	1.56898
4	-6.17628E-03	1.61827E-02	-.381659
9	-3.90019E-02	.103588	-.376511

INTERCEPT(A) 6.98974

TABLE OF RESIDUALS

OPS.	Y OBSERVED	Y ESTIMATED	RESIDUAL	STD. RESID.
1	2.000	2.928	-0.928	-1.110
2	2.000	2.953	-0.953	-1.140
3	3.000	2.732	0.268	0.320
4	3.000	2.732	0.268	0.320
5	3.000	2.752	0.248	0.296
6	4.000	3.637	0.363	0.435
7	4.000	3.991	0.009	0.011
8	4.000	5.270	-1.270	-1.519
9	5.000	4.084	0.916	1.095
10	5.000	5.037	-0.037	-0.044
11	5.000	4.944	0.056	0.067
12	5.000	4.574	0.426	0.509
13	5.000	5.231	-0.231	-0.276
14	5.000	5.037	-0.037	-0.044
15	6.000	5.409	0.591	0.707
16	6.000	5.399	0.601	0.718
17	7.000	7.288	-0.288	-0.345

COMPUTER OUTPUT-TBM AND RBM DATA ANALYSIS.

FIGURE 3-1

Ten sets of data were analyzed for conventional operations, using the values tabulated below:

DATA FOR ANALYSIS, CONVENTIONAL OPERATIONS										
Column		1	2	3	4	5	6	7	8	9
Ident. No.	Obs. No.	MDN	Class	f _c	RQD	DUW	H	GW	A/H	PF
LK-1	1	1	1	25	83	162	55	1	5.4	4.0
LK-2	2	1	1	28	83	165	55	1	5.4	4.0
LK-3	3	1	2	26	80	178	50	1	5.0	5.0
LK-4	4	2	2	14	70	181	47	1	4.4	5.5
GA-1	5	3	1	35	96	161	55	1	2.1	6.1
11-3	6	3	3	22	90	152	43	1	5.1	3.5
H-1	7	3	1	32	80	162	52	2	2.6	5.5
NAST-3	8	3	1	13	90	152	42	2	2.2	6.3
H-2	9	3	1	39	80	164	55	2	2.6	5.6
WNG-2	10	7	3	1	30	125	20	3	2.5	5.0

Results of the analysis, as shown in detail on Figure 3-2 following, indicate an accuracy of over 99 percent with a standard error of 0.2062 and the listed residuals.

Incorporation of additional data from subsequent field work and testing will improve the reliability of prediction, although it is doubtful that the accuracy indicated for conventional operations will be maintained at the level of the preliminary analysis. In additional iterations of the analysis, it is proposed to substitute values of Young's modulus and Poisson's ratio being accumulated in the current program for the less important parameters. Current efforts to obtain data on effective or net torque for TBM's, to develop appropriate parameters for analysis of the drag cutter TBM and shield MDN's, and to confirm inferred Schmidt hardness values will be continued to provide additional variables for analysis. Analyses with complete data are scheduled for the remainder of the current program.

3.6 TRANSPORT SYSTEM SELECTION

A list of equipment capabilities, system constraints, and MDN applications which comprised this section of the annual report of the first year's program is included as Appendix E.

MULTIPLE CORRELATION COEFFICIENT..... 0.9992
 F FOR ANALYSIS OF VAR. (D.F. = 8, 1) 82.4711
 STANDARD ERROR OF ESTIMATE..... 0.2062

VARIABLE	REG. COEFF.	STD. ERR-COEFF.	COMPUTED T
5	-1.82976E-02	4.70338E-02	-0.389031
9	-.237584	.534353	-0.444621
2	.75977	.787339	.964985
7	-1.37212	.48862	-2.80816
4	-3.41264E-02	9.69424E-03	-3.52028
8	-.879842	.801093	-1.0983
3	-3.07083E-02	4.55421E-02	-0.674285
6	4.07791E-02	.147084	0.277251

INTERCEPT(A) 15.7937

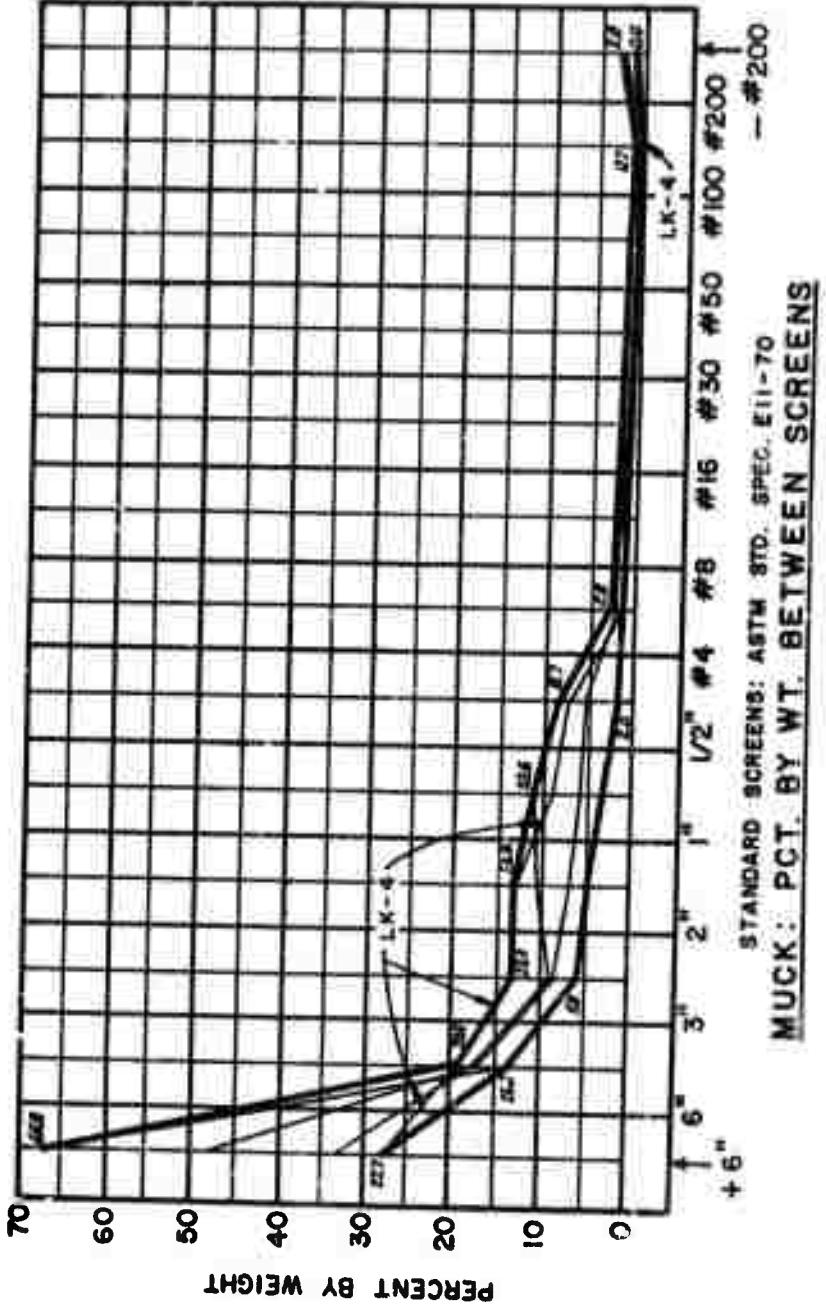
TABLE OF RESIDUALS

OBS. NO.	Y OBSERVED	Y ESTIMATED	RESIDUAL	STD. RESID.
1	1.000	1.065	-0.065	-0.318
2	1.000	0.918	0.082	0.395
3	1.000	1.069	-0.069	-0.336
4	2.000	1.954	0.046	0.221
5	3.000	3.013	-0.013	-0.065
6	3.000	2.983	0.017	0.080
7	3.000	3.115	-0.115	-0.558
8	3.000	2.978	0.022	0.109
9	3.000	2.898	0.102	0.495
10	7.000	7.005	-0.005	-0.022

COMPUTER OUTPUT-CONVENTIONAL DATA ANALYSIS.

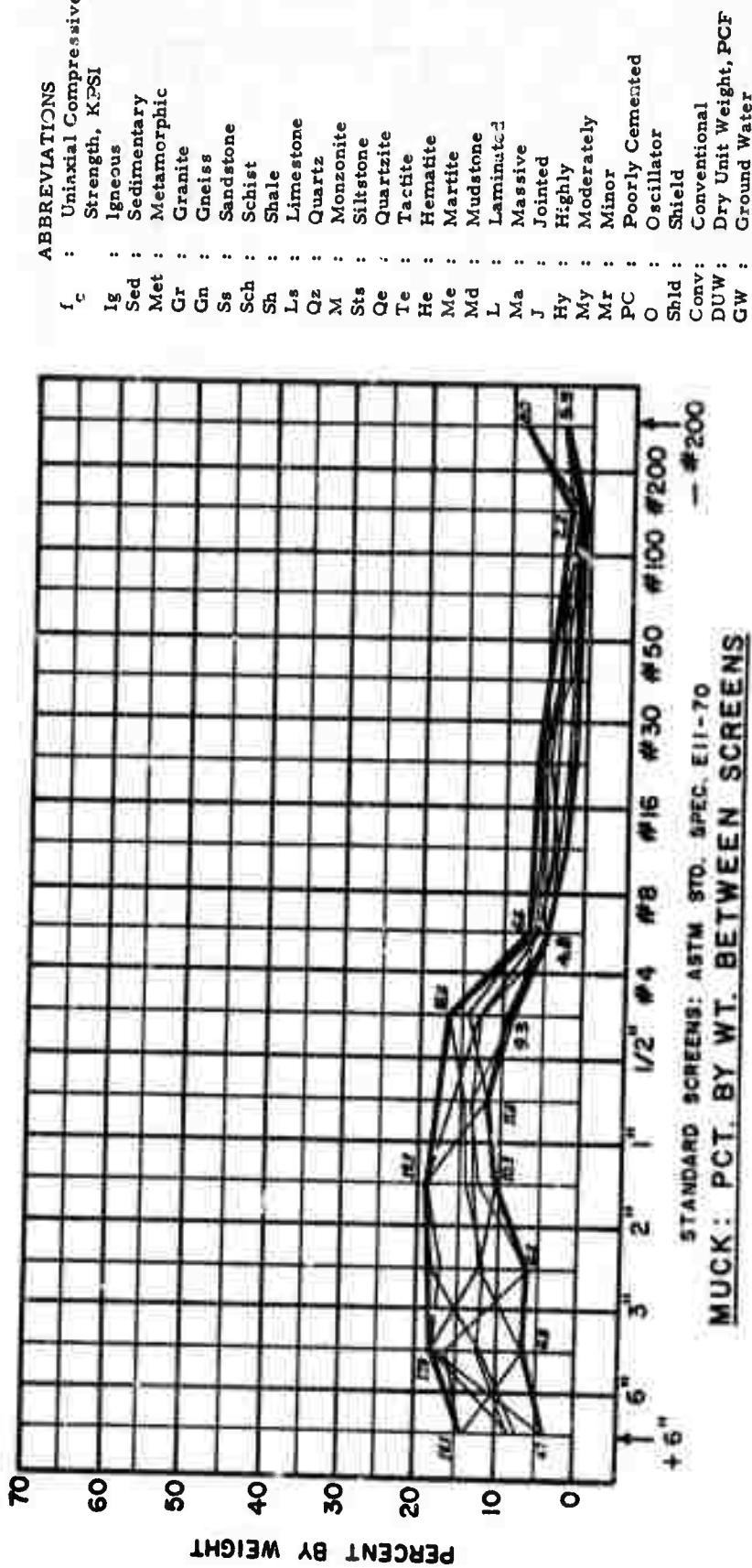
FIGURE 3-2

ABBREVIATIONS	
f	: Uniaxial Compressive Strength, KPSI
c	: Metamorphic
Ig	: Igneous
Sed	: Sedimentary
Met	: Metamorphic
Gr	: Granite
Gn	: Gneiss
Ss	: Sandstone
Sch	: Schist
Sh	: Shale
Ls	: Limestone
Qz	: Quartz
M	: Monzonite
Sts	: Siltstone
Qe	: Quartzite
Te	: Tactite
He	: Hematite
Me	: Martite
Md	: Mudstone
L	: Laminated
Ma	: Massive
J	: Jointed
Hy	: Highly
Mx	: Moderately
Mr	: Minor
PC	: Poorly Cemented
O	: Oscillator
Shld	: Shield
Conv	: Conventional
DUW	: Dry Unit Weight, PCF
GW	: Ground Water



^{**}Inferred from D. U. Deere, et al., AD 646 610-1966. **Regression Data List.

FIGURE 3-3: ROCK, TUNNEL, OPERATING, AND MUCK DATA, MDN T-1 AND T-2, CONVENTIONAL



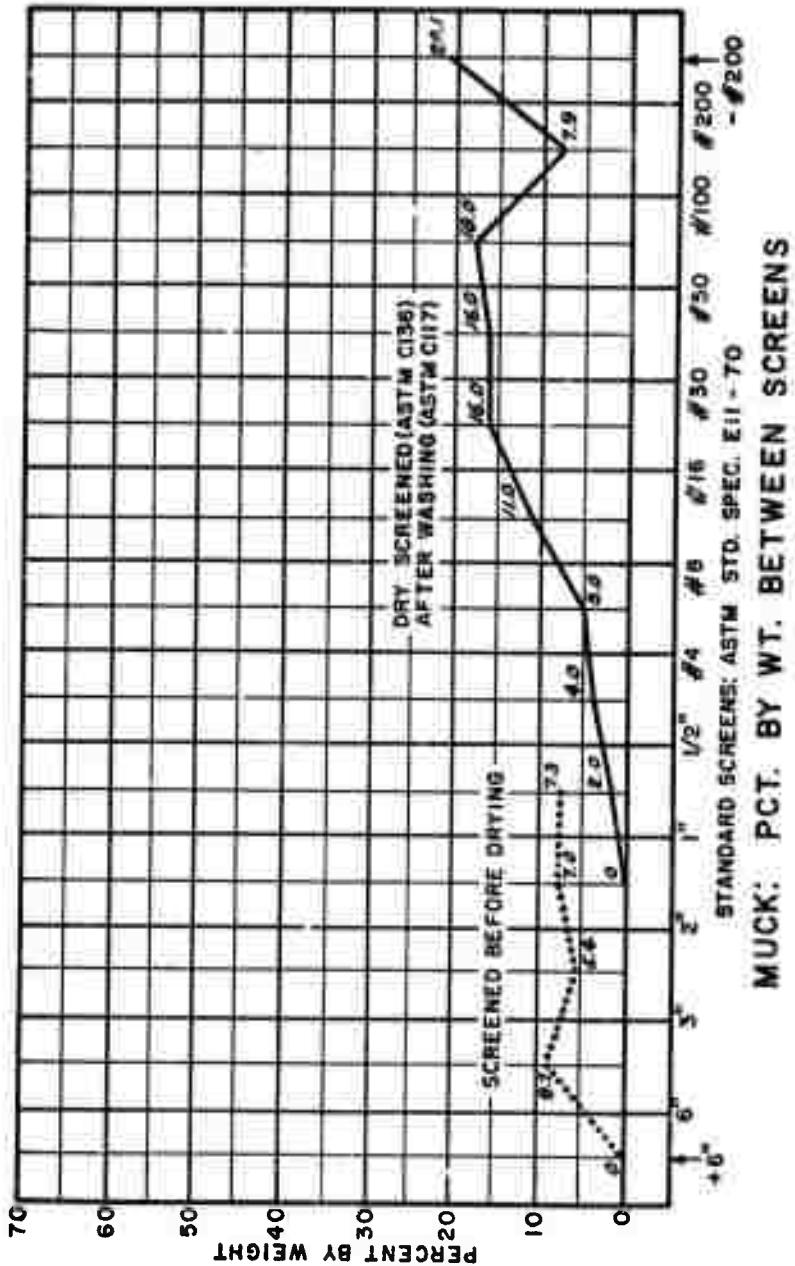
Inferred from D. U. Decr. et al. AD 646 610-1866

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FIGURE 3-4: ROCK, TUNNEL, OPERATING, AND MUCK DATA, MDN T-3, CONVENTIONAL

ABBREVIATIONS

f_c	: Uniaxial Compressive Strength, KPSI
Ig	: Igneous
Sed	: Sedimentary
Met	: Metamorphic
Gr	: Granite
Gn	: Gneiss
Ss	: Sandstone
Sch	: Schist
Sh	: Shale
Ls	: Limestone
Qz	: Quartz
M	: Monzonite
Sts	: Siltstone
Qe	: Quartzite
Te	: Tactite
He	: Hericatite
Me	: Martite
Md	: Mudstone
L	: Laminated
Ma	: Massive
J	: Jointed
Hy	: Highly
My	: Moderately
Mr	: Minor
PC	: Poorly Cemented
O	: Oscillator
Shld	: Shield
Conv	: Conventional
DUW	: Dry Unit Weight, PCF
GW	: Ground Water



IDENT. NO.	EXCAV. METHOD	MDN	CLASS	TYPE	STRUCT.	f_c	RQD	DUW	HARDNESS*	TUNNEL SIZE, FT.	GW Wet=3	SQ. FT. / HOLE	EXPL. #/CY.	MAX. SIZE OBSERVED
WNG-2	Conv	T-7	Sed=3	Ss	PC	1	30	125	20	5W x 9	2.5	5.0	18' x 10' x 11'	
COL. NO. #			1	2								7	8	9
							3	4	5	6				

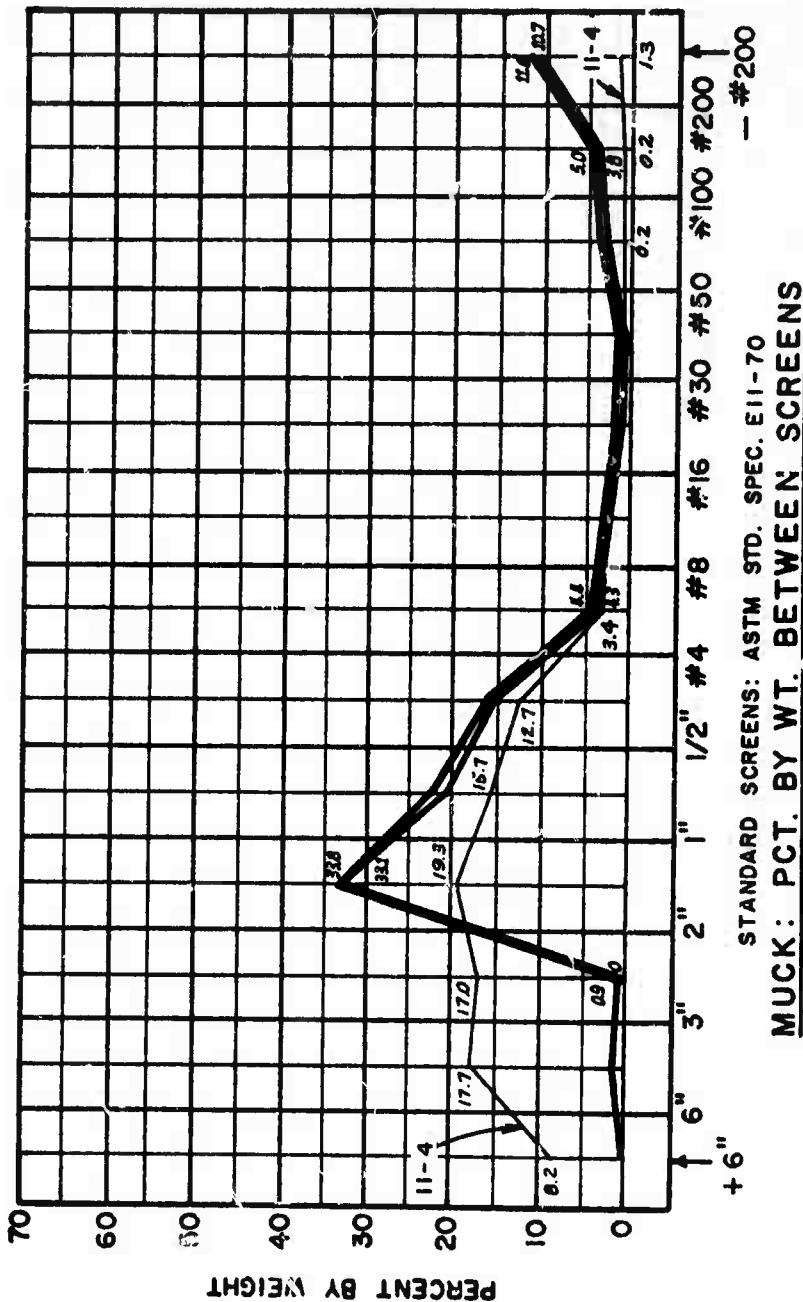
*Inferred from D. U. Deere, et al., AD 646 610-1966.

**Regression Data List.

FIGURE 3-5: ROCK, TUNNEL, OPERATING, AND MUCK DATA, MDN T-7, CONVENTIONAL

ABBREVIATIONS

f_c	: Uniaxial Compressive Strength, KPSI
Ig	: Igneous
Sed	: Sedimentary
Met	: Metamorphic
Gr	: Granite
Gn	: Gneiss
Ss	: Sandstone
Sch	: Schist
Sh	: Shale
Ls	: Limestone
Qz	: Quartz
M	: Monzonite
Sts	: Siltstone
Qe	: Quartzite
Tc	: Tactite
He	: Hematite
Me	: Martite
Md	: Mudstone
L	: Laminated
Ma	: Massive
J	: Jointed
Hy	: Highly
My	: Moderately
Mr	: Minor
PC	: Poorly Cemented
O	: Oscillator
Shld	: Shield
Conv	: Conventional
DUW	: Dry Unit Weight, PCF
GW	: Ground Water



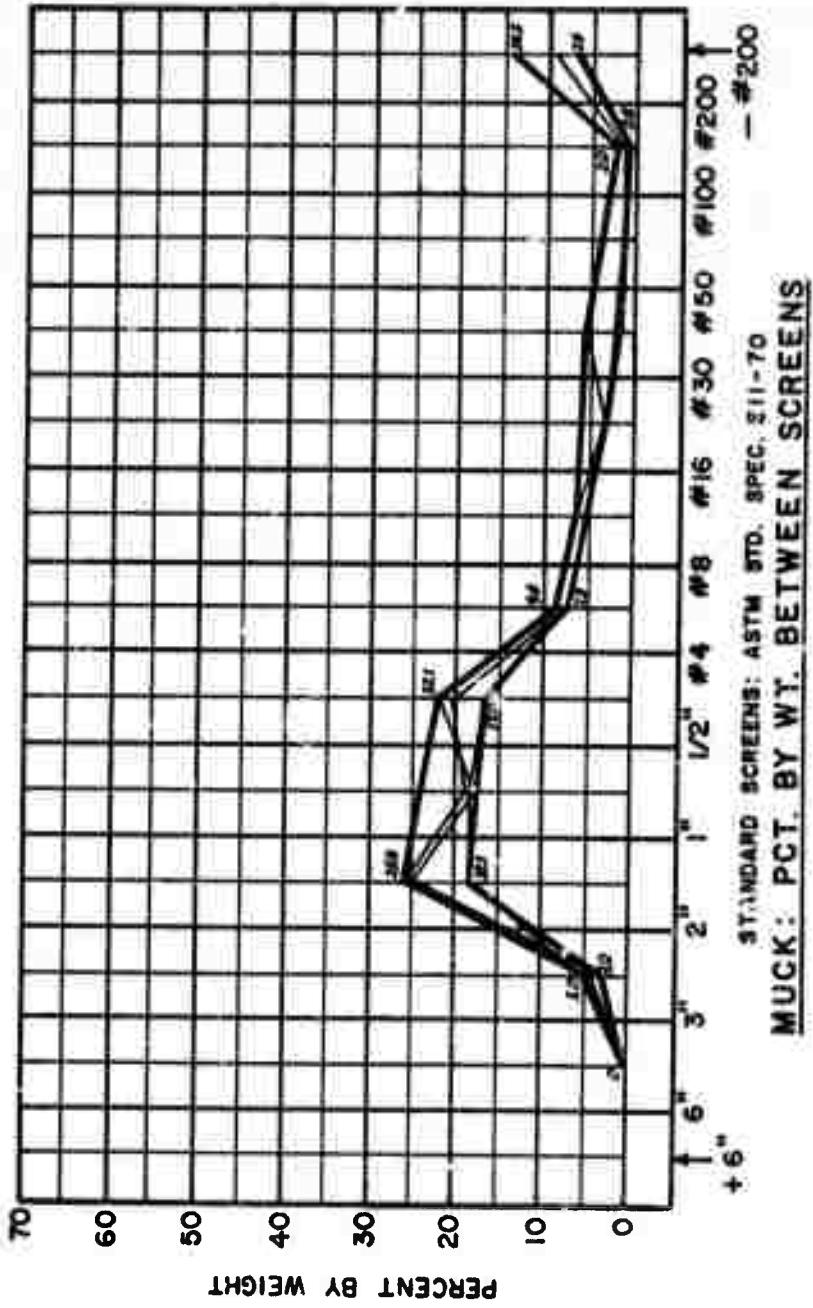
**Regression Data List.

Inferred from D. U. Deere, et al, AD 640 610-1966.

FIGURE 3-6: ROCK, TUNNEL, OPERATING, AND MUCK DATA, MDN T-1 AND T-2, MACHINE

IDENT. NO.	ENCA V. METHOD	MDN	ROCK PROPERTIES					TUNNEL SIZE, FT.	KERF SPACE	THRUST /SQ. FT.	MAX. SIZE OBSERVED
			CLASS	TYPE	STRUCT.	f_c	RQD				
11-4	TBN	T-1	Sed=3	Ms Sh	Ma Mr L	22	90	166	43	18W x 8.5	Dry=1 NA NA
5--	TBN	T-2	Sed=3	Ss	Ma	22	92	166	49	18.08 dia.	Dry=1 0.20 3.56K 2-1/2" x 8" x 3/4"
7-2	TBN	T-2	Sed=3	Ss	Ma	22	92	166	49	18.08 dia.	Dry=1 0.20 2.91K 3" x 9" x 1"
COL. NO.											
	1	2					3	4	5	6	7 8 9

ABBREVIATIONS	
f _c	Uniaxial Compressive Strength, KPSI
Ig	Igneous
Sed	Sedimentary
Met	Metamorphic

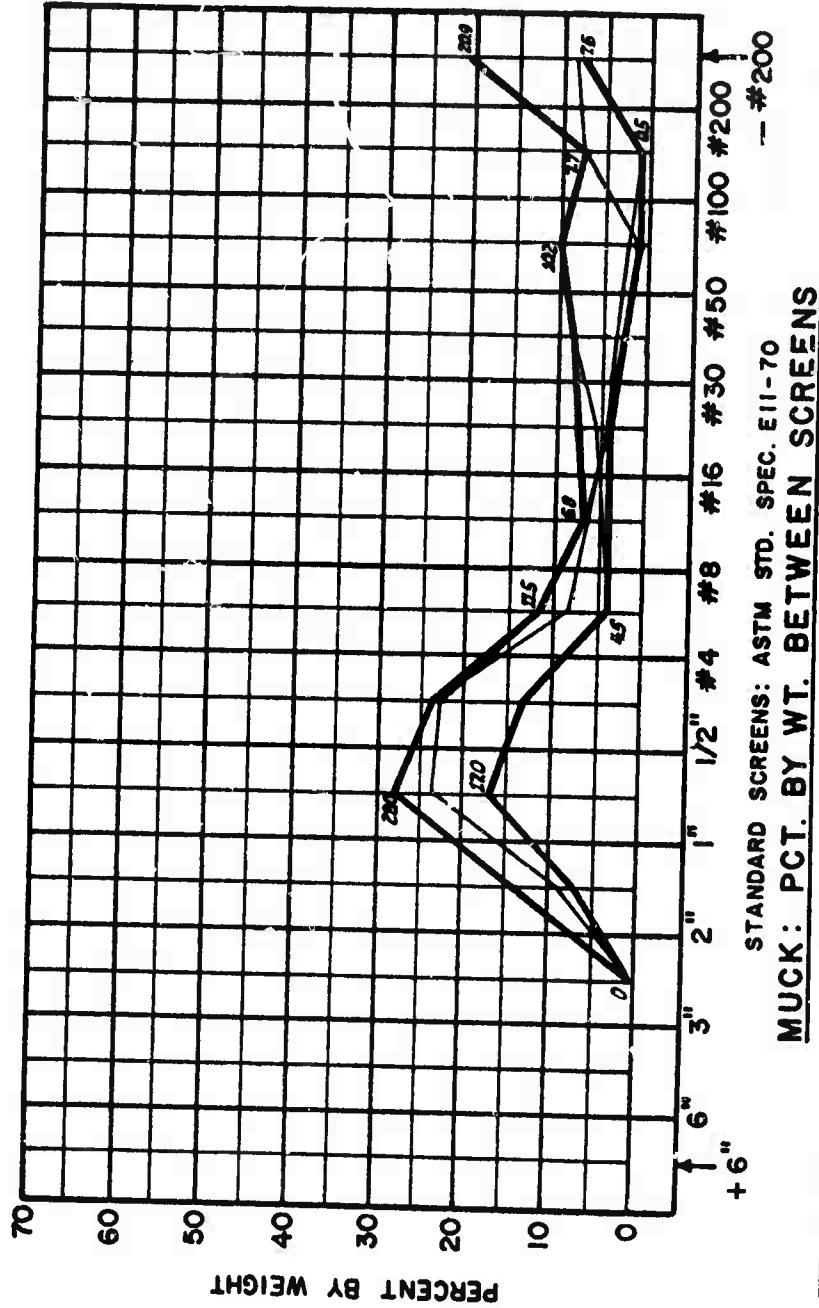


⁴Inferred from D. U. Deere, et al., AD 646 610-1966.

Regression Data List

FIGURE 3-7: ROCK, TUNNFL, OPERATING, AND MUCK DATA, MDN T-3, MACHINE

ABBREVIATIONS
 f_c : Uniaxial Compressive
 Strength, KPSI

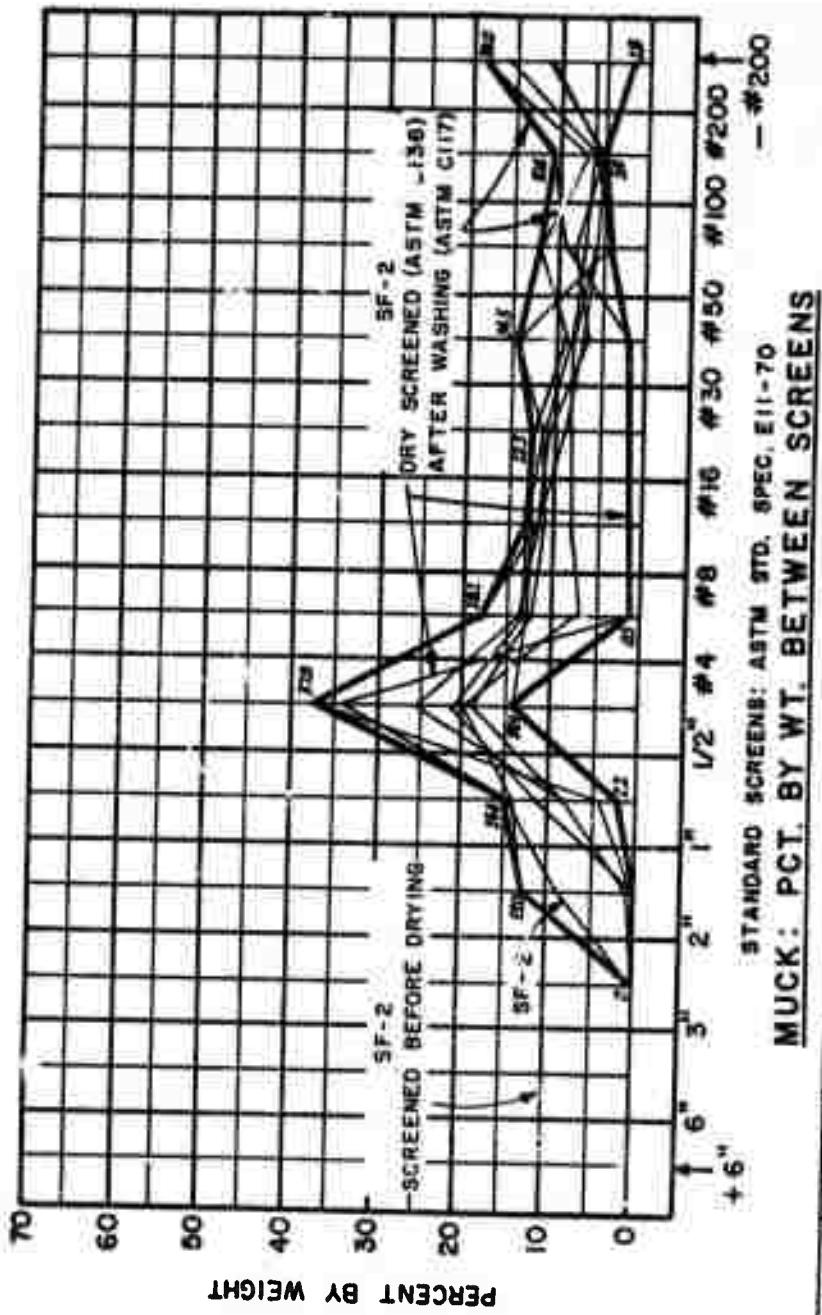


Inferred from D. U. Deere, et al., AD 646 610-1966.

FIGURE 3-8: ROCK, TUNNEL, OPERATING, AND MUCK DATA, MDN T-4, MACHINE

ABBREVIATIONS

U.	Uniaxial Compressive Strength, KPSI
Ig	Igneous
Sed	Sedimentary
Met	Metamorphic
Gr	Granite
Ch	Chert
Sa	Sandstone
Sch	Schist
Sl	Slate
Li	Limestone
Qu	Quartz
M	Mica-schist
St	Stalagmite
Qz	Quartzite
Te	Talcite
He	Hematite
Ma	Mica
Ms	Mica-schist
Ly	Laminated
Ma	Massive
J	Jointed
Hy	Highly
My	Moderately
Mr	Miscellaneous
PIC	Polarity Cementsation
O	Oscillatory
Shd	Shield
Concr	Concretes
DW	Dry Unit Weight, PCF
GW	Ground Water

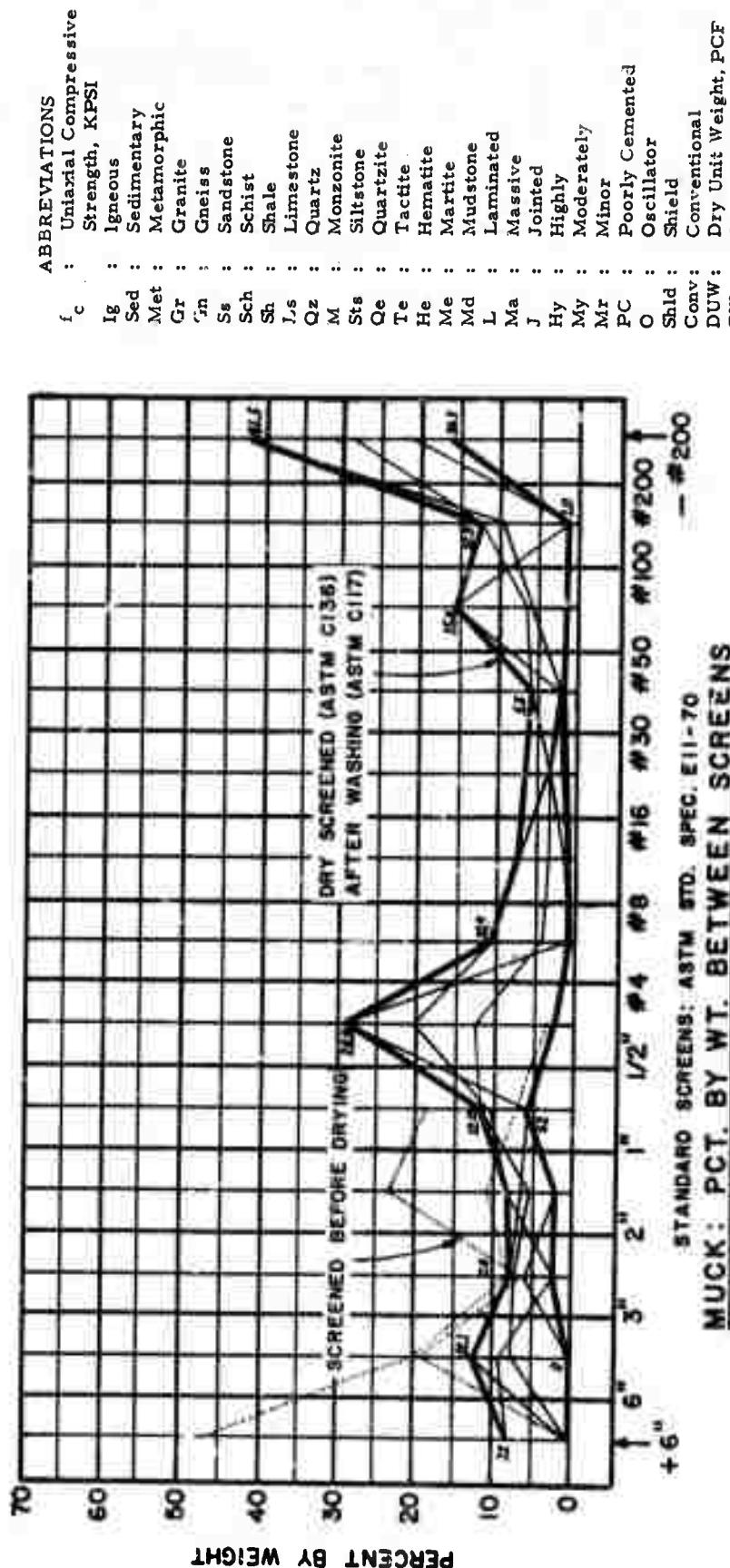


IDENT. NO.	EXCAV. METHOD	MDN	CLASS	TYPE	STRUCT., f _c	HOLD	DUW	HARDNESS:	TUNNEL		HEFT	THRUST / SQ. FT.	MAX. SIZE OBSERVED
									SIZE, FT.	SPACE			
CL-1	TBM	T-5	Met+2	Gr+Ch	Hy J	Y	10	174	45	1.5 dia.	2	0.99	5.09
SF-2	Solid	T-5	Sed+1	St	PC	Z	50	142	30	21 dia.	3	NA	1-1/2" x 2-1/2" x 3-1/4"
NAST-1	TBM	T-5	Ig+1	Gr	My J	18	90	167	55	9.75 dia.	3	0.99	3" x 2" x 8"
NAST-4	TBM	T-5	Ig+1	Gr	My J	74	90	160	55	9.53 dia.	2	0.99	3" x 1-1/2" x 1-1/2"
LR-5	RBM	T-5	Ig+1	Gr+M	My J	12	92	165	55	12 dia.	1	0.99	8.45
LR-6	RBM	T-5	Ig+1	Gr+M	Hy J	7	86	137	40	4 dia.	1	0.13	4-1/2" x 4-1/2" x 3-1/4"
NAST-1	TBM	T-5	Ig+1	Gr	My J	18	90	167	55	9.75 dia.	2	0.99	2-1/2" x 1-1/2" x 1-1/4"
COL. NO. =		1	Z			3	4	5	6		7	8	9

-Inferred from D. U. Deere, et al., AD-646-610-1966.

*Progression Data List.

FIGURE 3-9: ROCK, TUNNEL, OPERATING, AND MUCK DATA, MDN T-5, MACHINE AND SHIELD

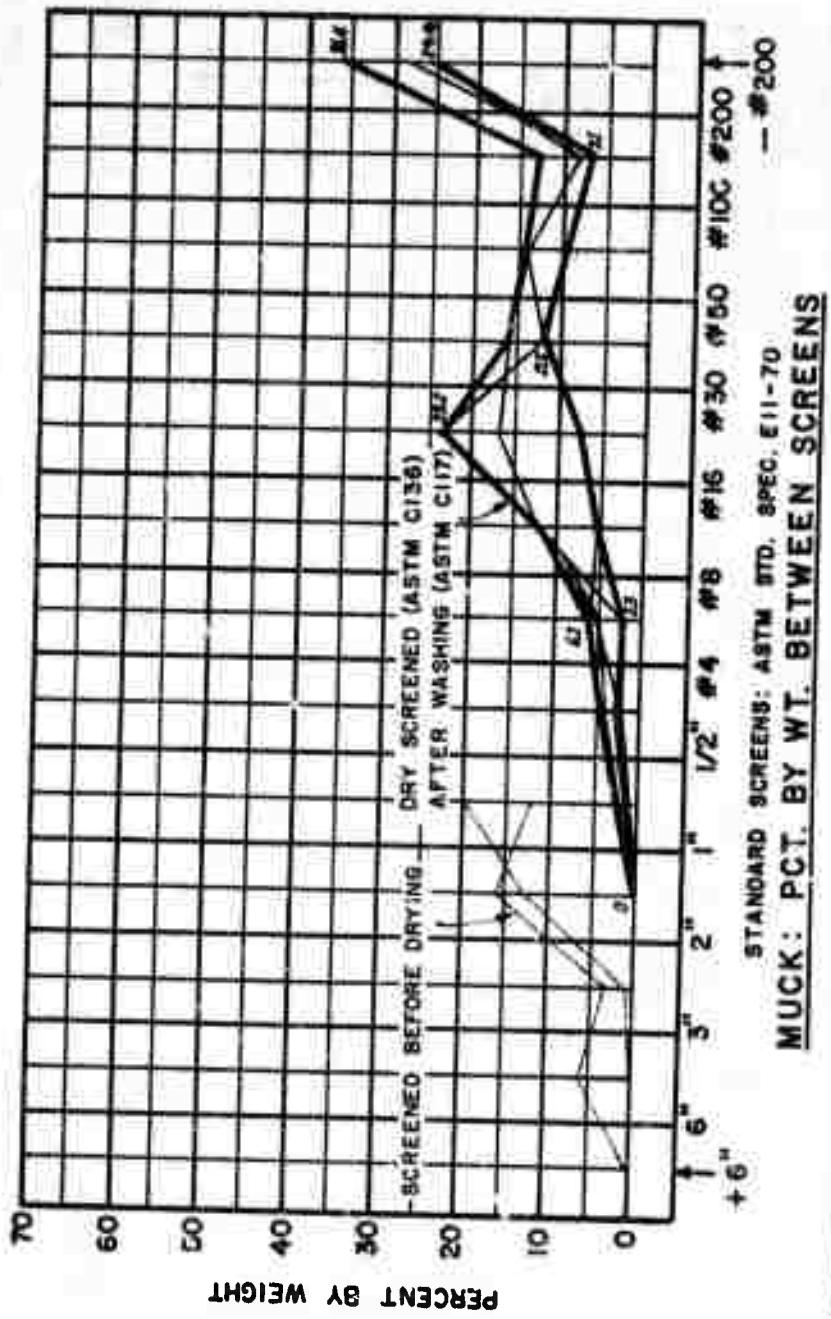


²Inferred from D. U. Decree, et al. AD 646 610-1366.

Regression Data 11-24

FIGURE 3-10: ROCK, TUNNEL, OPERATING, AND MUCK DATA, MDN T-6, MACHINE

ABBREVIATIONS	
f_c	Uniaxial Compressive Strength, KPSI
Ig.	Igneous
Sed.	Sedimentary
Met.	Metamorphic
Gr.	Granite
Onc.	Oncoids
Sh.	Sandstone
Sch.	Schist
Sh.	Shale
Ls.	Limestone
Qs.	Quartz
M.	Mica
Svs.	Silicate
Qs.	Quartzite
Tv.	Talcite
Hs.	Hematite
Ms.	Martite
Md.	Mudstone
L.	Laminated
M.s.	Micaschist
J.	Jacketed
Hy	Highly
My	Moderately
Mr.	Mineral
P.C.	Polymer Coated
O	Oscillations
Shld.	Shield
Conv.	Conventional
DUW	Dry Unit Weight, PCF
GW	Ground Water



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FIGURE 3-11: ROCK, TUNNEL, OPERATING, AND MUCK DATA, MDN T-7 MACHINE AND SINTER 2

inferred from D. H. Evans et al.

Belt conveyor and hydraulic transportation parameters have been studied under the current program. Standard belt conveyor design publications and available literature on hydraulic conveying were reviewed to determine the data required and the methods used in system designs.

The parametric mathematical models described in HN-8080 "Materials Handling for Tunnels," referenced in Appendix E, were reviewed for application in this study. It is apparent that muck size and size distribution, on which MDN's are based, as well as other physical property characteristics determined in the program can be used as input for the design formulae and the models.

Modification and refinement of the models, originally developed for the high advance rates of the future, will be necessary for direct application to current operations. Some design parameters are not well defined in the references, and further study will be necessary to resolve differences in design philosophy which appear in the literature.

A preliminary design of a hydraulic muck disposal system based on data from a TBM tunnel is in process. Comparison between a design based on study data and an extensive suspended conveyor installation is planned. One example of MDN application to each of the other transport systems will be provided.

4. DOD IMPLICATIONS

The data accumulated under the program are nonexistent in usable form elsewhere. While some TBM manufacturers and operators use muck size as an indicator of cutter efficiency, changes are noted during informal inspections at the machine and are seldom recorded except as showing a need for cutter replacement. A few screen analyses have been run, but results normally are not made available outside of a manufacturer's or contractor's organization.

Current selection of transportation systems usually is based on availability, intuition, and contractor familiarity with the equipment used at other sites. In some cases, the choice has been completely unsuitable for the muck produced. This has resulted in delays and additional expense which may be avoided by use of the information collected by the MDN study.

Previous investigations have indicated that major modifications of conventional equipment, or design of completely new systems, will be necessary to dispose of the muck from the high speed excavation systems predicted for the future. Muck characteristic data is a requisite as a basis for the engineering design of such system improvements or of innovative systems.

As an alternate to the design of a haulage system suitable for handling a particular muck, it may be practical to change muck characteristics at the face to provide a suitable feed for a handling system particularly well adapted to the tunnel site. MDN data will be invaluable to the selection of the necessary processing equipment.

A second alternate is in providing a continuous transport system such as hydraulic or pneumatic for the major volume of the muck, and temporary storage, as in a trailer or muck car, for a minor quantity of oversize which would be handled periodically. Again, muck characteristic data is a necessity to design the separation equipment and to estimate the capacity required in the secondary system.

In the course of the current program and subsequent use of the data produced, it is probable that potential improvements in transportation systems will appear. Where such improvements require the application of techniques which are technically sound but not developed to a point of practical application, they will be identified as attractive areas for research.

In summary, the current MDN program provides the basic data required for a rational, engineering approach to problem solutions in a most important subsystem of the rapid excavation process. It will show examples of data application and should be used to indicate the areas in which research and development of modifications or new methods would be most productive.

5. IMPLICATIONS FOR FURTHER RESEARCH

5.1 SAMPLE AND DATA COLLECTION

At the end of the current contract, it is expected that the following samples will have been collected, including 19 in 1972 and 1 collected but not tested in the 1971 program.

Excavation Method	Rock Strength					Total
	Very High	High	Medium	Low	Very Low	
Conventional	3	9	5	1	1	19
Shield	0	0	0	0	2	2
Machine						
Drag Cutters	0	1	1	2	1	5
Disc Cutters	2	7	5	1	0	15
Roller Cutters	0	4	1	0	0	5
Combination Cutters	0	3	1	1	2	7

At completion, the current program will have produced samples from 11 operations and/or formations which have not been sampled previously and which will be available for additional field work. To conform to good sampling and testing practice, the reliability of the data should be confirmed by repetition, preferably of all single tests.

While the major interest of the program is in strong rocks, variations in muck characteristics with strength can only be demonstrated by sampling the full range of rock strengths excavated by any one method. As they are available, additional sites should be sampled in formations of varied strength, such as the fine grained igneous and volcanic rocks.

Statistically, the number of samples used in developing a predictor equation should be greater than the number of the variables used in the analysis. Because the reliability of prediction is of major importance, additional samples should be obtained in the following operations:

1. Drag Cutter Machine excavation in High, Medium, and Low Strength rocks. These samples would provide a confirming data set in each strength category, and a total number of samples larger than the number of variables.

2. Roller Cutter Machine tunneling to provide enough data to analyze this method by a separate regression.
3. Combination Cutter Machine excavation in Low Strength rock to confirm data from a single sample collected previously.
4. Conventional tunneling in Low and Very Low Strength rocks to confirm data from single samples collected previously.
5. Disc Cutter Machine tunneling in Low Strength formations to improve the spread of the data on this method.
6. Disc Cutter Machine tunneling with tungsten carbide button insert cutters as a promising development in machine excavation of strong rocks.

5.2 PHYSICAL TESTING

Although problems have been encountered in obtaining consistent results from Schmidt hardness tests on core samples, development of test methods should continue because it is the only fast and inexpensive known test to measure the property of rocks.

Abrasiveness testing should be initiated as soon as possible and continued within the limit of available funds to provide data for the cost analysis phase of equipment selection.

The modified Protodyakonov test for resistance to fragmentation should be investigated for effectiveness and cost to evaluate development of data on this rock property for use in regression analysis and prediction of MDN's.

5.3 INNOVATIVE TECHNIQUES

Unusual rock breaking techniques now under development, such as the electron beam, the water cannon, the conical borer, and continuous application of explosives may become standard practice in the future. Sampling muck from tests of these methods whenever possible is recommended.

6. SPECIAL COMMENTS

A Schmidt rebound hardness tester and two MSA self-rescuers were purchased for use in the current program. No invention has been made in the course of the work performed under this contract.

GLOSSARY

ASTM	American Society for Testing and Materials	PF	Powder Factor
BM	Beam	PMSRC	Pittsburgh Mining and Safety Research Center
CFM	Cubic feet per minute	POT.	Potential
CNTR	Center	PSF	Pounds per square foot
COMPR.	Compressed	PSI	Pounds per square inch
CONTIN.	Continuous		
CONV	Conveyor	Rect.	Rectangular
CY	Cubic Yard	REG.	Regular
DEG.	Degrees	RBM	Raise Boring Machine
DIA.	Diameter	RPM	Revolutions per Minute
DUW	Dry Unit Weight	RQD	Rock Quality
Est, (E)	Estimated		Designation
FWD	Four Wheel Drive	SF	Square Foot
GPM	Gallons per Minute	ST	Scoop Tram
HP	Horse Power	SPECIF.	Specific
HRS.	Hours	STRNTH.	Strength
IN.	Inch	TBM	Tunnel Boring Machine
INTEG	Integral		
Inter.	Internal	TC	Tungsten Carbide
K	Thousand	TCB	Tungsten Carbide Button
LBS, #	Pounds		
LHD	Load Haul Dump	T	Tentative
LT	Long Ton	T.	Ton
MDN	Muck Designation	V	Volt
	Number	VOL	Volume
MAX	Maximum	W /	With
Moist.	Moisture	WT.	Weight
MM	Millimeter	'	Foot
NA.	Not Available	"	Inch
NO.	Number	#	Number
PCF	Pounds per Cubic Foot	%	Percent
PCT	Percent	(+)	Plus
		(-)	Minus

APPENDIX A
TUNNEL PROJECTS

Compiled by Holmes & Narver, Inc., Anaheim, California, under U. S.
Bureau of Mines Contract H0220023.

Revised September 1, 1972

NORTH AMERICAN CONTINENT

<u>Project and Location</u>	<u>Owner or Agency</u>	<u>Size</u>	<u>Length</u>	<u>Contractor</u>
Lakeshore Mine Casa Grande, Arizona	Hecla Mining Co. El Paso Natural Gas	14'x14' 14'x18' Plus Level Development	7,500'	Hecla Mining Company Own Force

The two 7,500' headings, declines at a minus 15°, are nearing completion. Levels are being developed at 900' and 1,400' vertically below the portal. Formations include mylonite, quartzite, tactite, and quartz monzonite. A raise boring machine has started a series of holes to the development levels.

Superior Mine Superior, Arizona	Magma Copper Company	10'x10'	Various	Own Force

Drifting on five levels to connect existing workings with a new shaft, now within 300' of completion at 4,200' depth. Formations are cretaceous conglomerate 7K to 10K psi, limestone 7K psi, quartzite to 20K psi. Operations are conventional.

San Manuel Mine San Manuel, Arizona	Magma Copper Company	12'x12'	Various	Own Force

Main level drifting on two levels in quartz monzonite and monzonite porphyry, concurrent with shaft sinking to 3,700' depth. A 9,000' drift is planned to explore a new ore body from the bottom level of the new shaft.

Tonner #1 and #2 Brea, Calif.	The Metropolitan Water District of Southern Calif.	11'6" Diameter	#1 - 4,589' #2 - 19,360'	Shea Construction Company

A Calweld machine is being assembled at the site to bore low strength sandstone and siltstone. Geologic data and cores are available from the owner agency.

<u>Project and Location</u>	<u>Owner or Agency</u>	<u>Size</u>	<u>Length</u>	<u>Contractor</u>
Hunter Tunnel Fryingpan Project Merideth, Colorado	U.S. Bureau of Reclamation Denver, Colorado	10'x10'	4.4 Miles	Granite Construction Company

A conventional operation in formations similar to the Nast tunnel. Lithologic and engineering property data have been collected from the U. S. Bureau of Reclamation. Excavation is scheduled for completion in October, 1972.

Nast Tunnel Fryingpan Project Merideth, Colorado	U.S. Bureau of Reclamation Denver, Colorado	10' Diameter	3 Miles	Peter Kiewit Sons Company
---	--	-----------------	---------	---------------------------------

A Wirth boring machine has been replaced by conventional drifting in fault zones, and is scheduled to resume work in more competent rock in November, 1972. Formations are predominantly granite, granite gneiss, granite porphyry, and granodiorite with compressive strengths from 18K to 24K psi. Rock is highly sheared in zones from a few feet to 400' thick.

Foggy Bottom Rosslyn Tunnel Section C-4 Washington, D.C.	WMATA Washington, D. C.	16'8" Diameter Finished	4,000' Each of Two Bores	Shea-Ball- S&M Construction J. V.
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Excavation by conventional methods in gneiss under the Potomac River. The schistose rock structure is reported to result in high shear strength and low compressive strength. Lithologic and engineering property data has been collected from the WMATA.

Crescent Mine Osburne, Idaho	Bunker Hill Company Kellogg, Idaho	10'x10'	Various	Own Force
---------------------------------	--	---------	---------	-----------

Conventional drifting on several levels. Trackless equipment is used on the lowest level, at 6,100' depth in quartzite, from which a lower level will be developed by a decline. The USBM Spokane Mining Research Center has collected voluminous rock property data at this site.

<u>Project and Location</u>	<u>Owner or Agency</u>	<u>Size</u>	<u>Length</u>	<u>Contractor</u>
Star Mine Burke, Idaho	Hecla Mining Company, Wallace, Idaho	9'x10'	Various	Own Force

Conventional drifting on several levels. Rail mounted equipment is in use on the lowest level, at 7,094' depth, in quartzite.

Mt. Greenwood Tunnel Chicago, Illinois	Dept. of Public Works, City of Chicago, Illinois	10'4" Diameter	1.8 Miles	S. A. Healy Construction Company
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A Robbins machine has finished Mt. Greenwood No. 1. Preparations are in progress to start Mt. Greenwood No. 2 in limestone, reported similar to that in the Mt. Greenwood No. 1. Geologic and rock data has been collected from the owner agency.

White Pine Copper Company White Pine, Michigan	Copper Range Company New York, New York	18'1" Diameter 18'x8-1/2' Rectangular	Various	Tunneling by White Pine With Own Force
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A Robbins machine, operating in sandstone since 1969, has passed through a conglomerate horizon into the overlying shale. An Atlas-Copco machine is operating in the shale. Normal drifting is conventional. Existing rock property data includes compression, Brazilian tensile, and Shore hardness test results.

Nevada Test Site Mercury, Nevada	USAEC and Defense Atomic Support Agency (DASA) Mercury, Nevada	Various	Various	Reynolds Electrical and Engineering Company
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Conventional and Alpine Miner tunnels may provide an opportunity for comparison of the muck produced by the two systems. Formations are volcanic tuffs which vary from 600 to 4,500 psi in unconfined compressive strength. Engineering property data has been collected by the U. S. Geological Survey and by DASA.

<u>Project and Location</u>	<u>Owner or Agency</u>	<u>Size</u>	<u>Length</u>	<u>Contractor</u>
Navajo Irrigation Project Farmington, New Mexico	U.S. Bureau of Reclamation Denver, Colorado	20.5' Diameter	3 Miles	Fluor-Utah Engineering & Construction Company

A Dresser boring machine is operating in sandstone with an unconfined compressive strength of less than 1K psi, and is expected to reach a 9.7K psi sandstone as the tunnel advances. Completion is scheduled for November, 1972.

Section 35 Uranium Mine Grants (Ambrosia Lake), New Mexico	Kerr-McGee Corporation	10'x10' and 8'x8'	Various	Kerr-McGee Own Force
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An Alpine Miner is operating in sandstone development headings, in which normal operations are conventional.

Kermac Potash Carlsbad, New Mexico	Kerr-McGee Corporation	13'x5'	Various	Own Force
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Goodman continuous miners are operating in salt-potash formations reported from 3K to 6K psi in strength.

Cross-Irondequoit Interceptor Tunnel, Rochester, New York	Dept. of Public Works, New York	18'4" Diameter	5-1/2 Miles	Tunnel Constructors (Greenfield-Ferrera-S.A. Healy, J. V.)
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A Lawrence TBM is operating in formations reported as shale, limestone, and sandstone, compressive strengths 2K to 20K psi. Geologic and rock data has been collected from the owner agency.

<u>Project and Location</u>	<u>Owner or Agency</u>	<u>Size</u>	<u>Length</u>	<u>Contractor</u>
New York City, New York Contract #13	Dept. of Public Works, New York, New York	11'6" and 8'6"	9,200'	Perini-B&R- G. H. Ball- S&M Constructors, J. V.

Two Jarva TBM's are operating in mica schist, with compressive strength reported 15K to 30K psi. Cores and rock test data are available from the owner.

Homestake Mine, Lead, South Dakota	Homestake Mining Company	7-1/2'x 8-1/2'	Various	Own Force
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Conventional main level development drifting at 150' vertical intervals to 7,100' depth in phyllites, quartz mica schists, quartzites, carbonates and silicates, ranging in strength from 5K to 40K psi.

Cross Town Wastewater Interceptor Austin, Texas	City of Austin, Texas	9' Diameter 10' Diameter	27,300' 30,500'	Granite Constr. Co. Peter Kiewit & Sons Company
--	--------------------------	-----------------------------------	--------------------	--

A Calweld machine will bore 30,500' in clays and limestones. A Robbins machine will bore 27,300' in limestones. Geologic and test data has been provided by the City of Austin.

Currant and Layout Tunnels Strawberry Aqueduct Heber City, Utah	U. S. Bureau of Reclamation Denver, Colorado	10'4" Diameter	Combined Length 4.9 Miles	S. A. Healy Construction Company
---	--	-------------------	---------------------------------	--

The Layout tunnel has been completed. A Robbins boring machine has started the Currant tunnel in conglomerate. Existing logs of drill holes show lithology. Compressive strength test results, from 14K psi to over 38K psi in the conglomerate, have been provided by the Bureau of Reclamation.

<u>Project and Location</u>	<u>Owner or Agency</u>	<u>Size</u>	<u>Length</u>	<u>Contractor</u>
Golden Goose II Uranium Mine Jeffrey City, Wyoming	Western Nuclear, Inc.	8' x 10'	Development Drifts	Owner Operated

An Alpine Miner equipped with a Serpentix conveyor is driving mining headings in soft sandstone. Conventional drifts are also being driven in similar formations.

Mathes "B" Mine	Cleveland Cliffs Iron Company Ishpeming, Michigan	10' x 10'	Various	Own Force
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Conventional timbered and untimbered development drifting on the 12th level in graywacke at 3,480' depth, conventional and Alpine Miner stope development in iron formation and ore above main levels.

APPENDIX B
RAW DATA SHEETS

<u>Identification</u>	<u>Page</u>	<u>Identification</u>	<u>Page</u>
NAST-1	B-1, B-2	5-1	B-51, B-52
NAST-2	B-3, B-4	7-2	B-53, B-54
NAST-3	B-5, B-6	11-3	B-55, B-56
NAST-4	B-7, B-8	11-4	B-57, B-58
GA-1	B-9, B-10	72-1	B-59, B-60
H-1	B-11, B-12	MSU-1	B-61, B-62
H-2	B-13, B-14	MSU-2	B-63, B-64
LK-1	B-15, B-16	LAW-2	B-65, B-66
LK-2	B-17, B-18	LAW-3	B-67, B-68
LK-5	B-19, B-20	LAW-4	B-69, B-70
LK-6	B-21, B-22	MIL-1	B-71, B-72
LK-7	B-23, B-24	MIL-2	B-73, B-74
SM-1	B-25, B-26	MIL-3	B-75, B-76
CL-1	B-27, B-28	EVG-1	B-77, B-78
LK-3	B-29, B-30	EVG-2	B-79, B-80
LK-4	B-31, B-32	LAY-1	B-81, B-82
MB-1	B-33, B-34	LAY-2	B-83, B-84
MB-3	B-35, B-36	NAV-1	B-85, B-86
ST-1	B-37, B-38	NAV-2	B-87, B-88
CR-1	B-39, B-40	RO-1	B-89, B-90
HS-1	B-41, B-42	WNG-1	B-91, B-92
NY-1	B-43, B-44	WNG-2	B-93, B-94
NY-2	B-45, B-46	SF-1	B-95, B-96
QL-1	B-47, B-48	SF-2	B-97, B-98
MB-2	B-49, B-50	KM-1	B-99, B-100

B-i

APPENDIX B
RAW DATA SHEETS

B-ii

MUCK	DATA	MOISTURE	PCT(%)	PER CENT BY WEIGHT BETWEEN SCREENS						PCT (-)					
DRY	UNIT	WT	PCT	6IN.	3IN.	2IN.	1/2IN.	NO4	NO8	NO16	NO30	NO50	NO100	NO200	ND200
83	9.4	0.0		0.0	0.0	0.0	2.2	14.9	12.5	12.4	12.3	6.6	11.8	6.8	18.5

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDING C=CUBIC I=IRREGULAR E=ELONGATED SPHEROID

PI	AI	AI	AI	SI	S
LIQUID LIMITS PCT	PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	SIZE (-) INCHES	PLASTICITY INDEX PCT	FLOW INDEX PCT
0	16.50	14.00	19.50	0.50	3.00

(-0.50IN. SIZE SPECIFIC GRAVITY) 0.50 IN. MATERIAL SIZE (-0.50 IN. ANGLE/REPOSE 1 IN. DROP DEGREES AT 9.0 PCT MOIST ANGLE/SL10E 10 IN. DROP DEGREES AT 9.0 PCT MOIST APPARENT COHESION PSF AT 9.0 PCT MOIST BULK DENSITY PCF AT 9.0 PCT MOIST FRICTION DEGREES AT 9.0 PCT MOIST

2.69 37 36 41 NA NA 42

NAST-1 CURRENT: 1 SEPT. 1972

KEY

1A
TUNNEL DATA

TUNNEL	SHAPE	GRADE	CFM	PRESS	EXHST	VENTILATION	SIZE	HP	GPM	WATER INFLOW	UTILITY LINES	POWER SYSTEM
SIZE 9FT 9IN	ROUND	+0.22PCT	10K	X	X		22IN			AIR 6IN	WATER 2IN	PRIMARY 4160V
MUCK RAIL	36IN GAGE.	70LB RAIL.	16 CY				SUPPLY RAIL			PUMP 6IN		SECONDARY 480V

HAULAGE SYSTEM

MUCK	PERSONNEL	BUILT TYPE	SIZE	ROOF PLATE	SET SIZE	SHAPE
RAIL	RAIL	4-11IN X TFT	13IN X 10FT	4IN RING AND HALF		
RAIL	GROUTED	16 GAGE	16 GAGE	SETS 4FT. 3FT. AND		
CARS				2FT IN BAD GROUND		
MOTOR 12 TON						

MACHINE EXCAVATION

MACHINE	MAKE	MODEL	WT	CUTTERS, MAKE, TYPE, DIAM, CUTTING EDGES	INTERIOR	GAGE	HEAD CENTER	HEAD HEAD	TORQUE, MAX/OPERATE	THRUST, MAX/OPERATE
WIRTH ERKELINZ	HAROPOCK	67 TONS	2 HUGHES 5' WIDTH TCB 11.5IN ROLLER 2-TITCH 11.5IN TCB CONE	2 HUGHES 5' WIDTH TCB 11.5IN ROLLER 2-TITCH 11.5IN TCB CONE	6 HUGHES/width TCB 11.5IN ROLLER	8.5 INTEG	KFTLB 150 KFTLB 110	KFTLB 150 KFTLB 110	HEAD CENTER	HEAD CENTER

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
KLB	BUCKET FROM FACE. 22IN CONVEYOR TO REAR	HYDRAULIC, POWERED BY 3-200HP MOTORS	LASER	KLB 3.69

CONVENTIONAL EXCAVATION

MACHINE	ROUND, NO. HOLES DEPTH DIAM. CUT.	BLASTING	MUCKING	GUIDANCE
JUMBO MACHINES				
FEED LENGTH				

EXPLOSIVES,
POWDER FACTOR
TOTAL LAS.
PRIMERS,
TRIM
INTERIOR
CUT
LIFTERS

KEY IDENTIFICATION
2 NAST

ROCK PROPERTIES
IGNEOUS: GRANITE, GRAY, MEDIUM
TO FINE GRAINED, MODERATELY TO
SLIGHTLY FRACTURED AND JOINTED
10 TO 20 PCT QUARTZ SO TO 60
PCT FELDSPAR HALANCE DARK
GENERALES.

MUCK DATA
DRY UNIT MOISTURE PCT 16 * * * * PER CENT BY WEIGHT BETWEEN SCREENS...
WT PCF IN SIZE 6IN. 3IN. 2IN. 1IN. 1/2IN. NO8 NO16 NO30 NO50 NO100 NO200
SAMPLE NO
NAST-2
PCT FELDSPAR HALANCE DARK
167 18 90 NA NA NA

MUCK DATA
DRY UNIT MOISTURE PCT 16 * * * * PER CENT BY WEIGHT BETWEEN SCREENS...
WT PCF IN SIZE 6IN. 3IN. 2IN. 1IN. 1/2IN. NO8 NO16 NO30 NO50 NO100 NO200
NAST-2
PCT FELDSPAR HALANCE DARK
167 18 90 NA NA NA

	76	10.8	0.0	0.0	0.8	8.0	25.0	13.8	11.5	10.3	6.6	7.7	5.5	10.8	
POT VOL CHANGE (-10.056 IN.SIZE															
SPECIF GRAVITY	0	19.5	18.2												
ANGLE/REPOSE 1 IN DROP															
DEGREES AT 0.7 PCT MOIST															

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUND P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=Spherical

B-3

PI PI PI AI AI SI SI S

	PI	PI	PI	AI	AI	SI	SI	S
POT VOL CHANGE (-10.056 IN.SIZE								
LIQUID LIMIT PCT								
PLASTIC LIMIT PCT								
ATTENBERG LIMITS SPRINKAGE LIMIT PCT								
SIZE (-) 0.50IN. SIZE ANGLE/REPOSE 1 IN DROP								
DEGREES AT 0.7 PCT MOIST								

	PI	PI	PI	AI	AI	SI	SI	S
POT VOL CHANGE (-10.056 IN.SIZE								
LIQUID LIMIT PCT								
PLASTIC LIMIT PCT								
ATTENBERG LIMITS SPRINKAGE LIMIT PCT								
SIZE (-) 0.50IN. SIZE ANGLE/REPOSE 1 IN DROP								
DEGREES AT 0.7 PCT MOIST								

	PI	PI	PI	AI	AI	SI	SI	S
POT VOL CHANGE (-10.056 IN.SIZE								
LIQUID LIMIT PCT								
PLASTIC LIMIT PCT								
ATTENBERG LIMITS SPRINKAGE LIMIT PCT								
SIZE (-) 0.50IN. SIZE ANGLE/REPOSE 1 IN DROP								
DEGREES AT 0.7 PCT MOIST								

	PI	PI	PI	AI	AI	SI	SI	S
POT VOL CHANGE (-10.056 IN.SIZE								
LIQUID LIMIT PCT								
PLASTIC LIMIT PCT								
ATTENBERG LIMITS SPRINKAGE LIMIT PCT								
SIZE (-) 0.50IN. SIZE ANGLE/REPOSE 1 IN DROP								
DEGREES AT 0.7 PCT MOIST								

NAST-2 CURRENT: 1 SEPT. 1972

MEY

TUNNEL DATA

TUNNEL

POWER SYSTEM						
TUNNEL	VENTILATION	WATER INFLOW	UTILITY LINES	PUMP	PRIMARY	SECONDARY
SIZF 9FT ROUND	GRADE +0.22PCT	CFM 10K	PRESS EXHST X	SIZE 22IN	GPM 5-20	'x' 6IN 2IN 6IN 6IN 6IN 6IN

卷之三

HAULAGE SYSTEM	SUPPORT SYSTEM	PERSONNEL RAIL	SUPPLY RAIL	ROOF PLATE 4 IN X 7FT GROUPED APPROX. 1200FT	SET SIZE 4 IN RING AND HALF SETS 4 FT. 3FT. AND 2FT IN BAD GROUND APPROX. 650FT	SHOTCRETE
MUCK RAIL, 16IN GAGE 70LR RAIL, 16 GAGE 70LR RAIL, 16 GAGE CARS MOTOR 12 TON						

MACHINERY EXCAVATION

MACHINE	CUTTERS, MAKE, TYPE, U.I.A.M., CUTTING EDGES	RPM	TORQUE, MAX/OPERATE	THRUST, MAX/OPERATE				
HAKKE WIRTH ERKELLENZ	MONEL HARONCK TONS	WT CENTER 2 HUGHES/WIRTH TCB II .5IN POLLEK, 2-TCB 11.5IN CONE	INFRIOR 6 HUGHES/WIRTH TCB II .5IN RULLER	HEAD, CENTER 8.5 INTEG	HEAD CENTER	KFTLB 150 KFTLB 110	KFTLB KFTLB	KLB 290
ANCHOR PRESS	MUCK SYSTEM BUCKETS FROM FACE, 22IN CONVEYOR TO 2EAR	POWER SYSTEM HYDRAULIC, POWERED BY 3-200HP MOTORS	GUIDANCE LASER	THRUST/SQ FT	KLH 3.69			
KLB								

CONVENTIONAL EXCAVATION

MACHINE
JUMBO
MACHINES

**EXPLOSIVES,
POWER FACTOR
TOTAL LBS
PRIMERS,
THIN
INTERIOR
CUT
LIFTERS**

BE ACTING MUSICKING GUIDANCE

NAST-2 CURRENT: 09/01/72

KEY 3 IDENTIFICATION ROCK PROPERTIES
 IGNEOUS: BIOTITIC GRANITE FINE
 GRAINED, MAJOR QUARTZ, MINOR
 FELDSPAR AND DARK MINERAL
 CONTENT.

MUCK DATA
 DRY UNIT MDISTURE PCT (+) 6
 JT PCF IN SIZE 6IN. 3IN. 2IN. 1IN. 1/2IN.
 PER CENT BY WEIGHT BETWEEN SCREENS
 ND4 ND8 ND16 ND30 ND50 ND100 ND200
 PCT (-)
 NO200

117 3.4 14.5 16.2 6.2 12.6 13.7 8.9 8.8 5.3 6.1 2.6 2.8 1.5 3.8

MUCK DATA
 DRY UNIT MDISTURE PCT (+) 6
 JT PCF IN SIZE 6IN. 3IN. 2IN. 1IN. 1/2IN.
 PER CENT BY WEIGHT BETWEEN SCREENS
 ND4 ND8 ND16 ND30 ND50 ND100 ND200
 PCT (-)
 NO200

117 3.4 14.5 16.2 6.2 12.6 13.7 8.9 8.8 5.3 6.1 2.6 2.8 1.5 3.8

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUND P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

A1 A1 A1 A1 A1 A1 A1

POT VOL CHANGE (+) 0.056 IN.SIZE LIQUID PLASTIC ATTERBERG LIMITS SIZE (+) 0.056 IN. PLASTICITY INDEX F0w INDEX TDUGNESS INDEX
 IN. SIZE PCT SHRINKAGE LIMIT PCT PCT PCT

0 19.50 17.41 17.13 2.63 4.10 0.51

(-) 0.7IN.SIZE ANGLE/REPPOSE MATERIAL SIZE (+) 2.0 IN APPARENT BULK
 SPECIF GRAVITY 1 IN. DROP ANGLE/SLIDE COHESION DENSITY
 DEGREES AT 10 IN. DROP STEEL PLATE PSF AT PCF AT
 2.8 PCT MOIST DEGREES AT 2.8 PCT MOIST 3.0 PCT MDIST 0.0 PCT MDIST 3.0 PCT MDIST
 2.65 39 36 31 80 91.2 38

38

NAST-3 CURRENT: 1 SEPT. 1972

40

CHANNEL DATA

卷之三

MACHINE MAKE	MODEL	WT CENTER	CUTTERS, MAKE + TYPE, UHMW + CUTTING EDGES	RPM	TORQUE, MAX/OPERATE	THRUST, MAX/OPERATE
			INTERIOR	HEAD + CENTER	HEAD	CENTER
			GAGE	KFT/LB	KFT/LB	KLB
				KFT/LB	KFT/LB	KLB

CONVENTIONAL EXCAVATION

MACHINING
 MACHINES JACK LEG 2-5S3F
 EEO LENGTH 4FT
 ROUND.
 NO. HOLES 72
 DEPTH 9FT
 DIAM. 1-3/4 IN
 CUT. DOUBLE V
 SF/HOLE 2.02

**EXPLOSIVE
POWER** :
TOTAL LB.
PRIMERS,
TRIM
INTERIOR
CUT

BLASTING **HUCKING**
ELECTRICAL **1/2CY DIESEL**
0-7 REGULAR **FRONT ENO**
DELAYS **LOADER**

NAST-3

CURRENT: 09/01/72

KEY IDENTIFICATION
4
NAST
SAMPLE NO
NAST-4

ROCK PROPERTIES
IGNEOUS, GRANITE, FINE GRAINED
MODERATELY FRACTURED, MAJOR
QUARTZ AND MINOR FELDSPAR
CONTENTS.

DRY UNIT
WT PCF
MOISTURE
PCT

16.0
24
90
NA
NA
NA

MUCK DATA
DRY UNIT
WT PCF
MOISTURE
PCT (+) 6
IN. SIZE
6IN. 3IN.
PER CENT BY
WEIGHT BETWEEN
SCREENS
1IN. 1/2IN.
NO₄ NO₈
NO₁₆ NO₃₀
NO₅₀ NO₁₀₀
NO₂₀₀
NO₄₀₀
PCT (-)
NO₂₀₀

83	17.2	0.0	0.0	0.0	11.5	20.6	13.6	12.7	11.0	14.5	4.4	5.8	5.9
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SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SQUARE ANGULAR R=ROUND E=IRREGULAR C=CUBIC P=PAPLTY

P_E P_I P_E A_I A_E A_I A_E

PDT VOL CHANGE
(-) 0.056 IN SIZE
LIQUID PLASTIC SHRINKAGE SIZE (-) 0.056 IN.
LIMIT LIMIT INDEX FLOW INDEX
PCT PCT PCT
19.20 18.97 17.50 0.23 3.40 0.06

(-) 0.7 SIN. SIZE
SPECIF GRAVITY
ANGLE/REPOSE
1 IN. DROP
DEGREES AT
6.0 PCT MOIST

MATERIAL SIZE (-) 2.0 IN.
ANGLE/SLIDE
10 IN. DROP
DEGREES AT
6.4 PCT MOIST

APPARENT
COHESION
PSF AT
7.1 PCT MOIST

BULK
DENSITY
PCF AT
0.0 PCT MOIST

2.64	39	34	40	0	91	33
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NAST-4 CURRENT: 1 SEPT. 1972

KEY

4A
TUNNEL DATA

TUNNEL	VENTILATION			WATER INFLOW			UTILITY LINES			POWER SYSTEM		
SIZE 9FT 10IN	SHAPE ROUND	GRADE +0.22PC	CFM 10K	PRESS EXHST X	SIZE 22IN	H.P. 5-20	AIR 6IN	WATER 2IN	PUMP 6IN	PRIMARY 4160V	SECONDARY 480V	
HAULAGE SYSTEM												
MUCK RAIL • 36IN GAGE • 70L3 RAIL • 16 CY CARS MOTOR 12 TONS	PERSONNEL RAIL	SUPPLY RAIL	BOLT, TYPE 4-11IN X 7FT GROUTED APPROX. 1200FT	ROOF PLATE 13IN X 10FT 16 GAGE	SET, SIZE, SHAPE 6IN RING AND SETS, 4FT, 3FT, AND 2FT IN BAD GROUND APPROX. 650FT		SHOTCRETE					

MACHINE EXCAVATION

MACHINF	CUTTERS, MAKE, TYPE, U.I.A.M., CUTTING EDGES			RPM			TORQUE, MAX/OPERATE			THRUST, MAX/OPERATE		
MAKE WIRTH ERKELLENZ HUGHES HEAD	MODEL HARDROCK	WT 67 TONS	CENTER 2 HUGHES TCH 11.5IN ROLLER, 2-11.5IN CONE	INTERIOR 6 HUGHES TCH 11.5IN ROLLER	GAGE 8.5 INCH	HEAD INTEG	HEAD KFTLB150 KFTLB125	HEAD KFTLB KFTLB	CENTER KFTLB KFTLB	BLASTING	MUCKING	GUIDANCE
ANCHOR PRESS KLB	MUCK SYSTEM BUCKET FROM FACE, 22FT CONVEYOR TO REAR	POWER SYSTEM HYD. 4LIC POWERED BY 3-250HP MOTORS	GUIDANCE LASER	THRUST/SQ FT KLB 8.45						EXPLOSIVES, POWDER FACTOR TOTAL LBS PUMPS, TRIM INTERIOR CUT LIFTERS		

CONVENTIONAL EXCAVATION

MACHINE JUMBO MACHINES	ROUND, NO. HOLES DEPTH DIAM. CUT,	BLASTING	MUCKING	GUIDANCE
FEED LENGTH				

KEY IDENTIFICATION
5 GRANITE ADIT
SAMPLE NO
GA-I

ROCK PROPERTIES
IGNOUS: GRANITE, MASSIVE,
MAJOR QUARTZ AND FELDSPAR,
MINOR OAK, MINERAL CONTENT.

DRY UNIT WT	MOISTURE PCT	PCT (+)16 IN. SIZE	ORY WT PCF	COMPR STRNTH KPSI	ROD PCF EST	SHORE MOH SCHMIDT
		6IN. 3IN. 2IN. 1IN. 1/2IN.	N04 N08 N016 N030 N050 N0100	N0200	N0200	
114	1.9	4.7	17.9 12.2 10.3 11.7	14.4 6.6	5.6 5.6	3.7 3.6
					0.2	3.5

MUCK DATA	DRY UNIT WT	MOISTURE PCT	PCT (+)16 IN. SIZE	PER CENT BY WEIGHT BETWEEN SCREENS	SIZE (-) 0.056 IN. SIZE	PLASTIC LIMIT PCT	LIQUID LIMIT PCT	SHRINKAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX	TOUGHNESS INDEX
			6IN. 3IN. 2IN. 1IN. 1/2IN.	N04 N08 N016 N030 N050 N0100	N0200						
	114	1.9	4.7	17.9 12.2 10.3 11.7	14.4 6.6	5.6 5.6	3.7 3.6	0.2	3.5		

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDEO P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPhEROID

A I A I A I A I A I A I A I

POT VOL CHANGE (-) 0.056 IN. SIZE	ANGLE REPOSE IN DEGREES AT 0.9 PCT MOIST	MATERIAL SIZE (-) 12.0 IN	ANGLE SLIDE IN DEGREES AT 0.9 PCT MOIST	APPARENT COHESION PSF AT 0.9 PCT MOIST	BULK DENSITY PCF AT 0.9 PCT MOIST	ANGLE INTER FRICTION DEGREES AT 0.9 PCT MOIST
		0.056	12.0	0.42	3.00	0.14
0	16.2	15.78	13.67			

SPECIFIC GRAVITY	ANGLE REPOSE IN DEGREES AT 0.9 PCT MOIST	MATERIAL SIZE (-) 12.0 IN	ANGLE SLIDE IN DEGREES AT 0.9 PCT MOIST	APPARENT COHESION PSF AT 0.9 PCT MOIST	BULK DENSITY PCF AT 0.9 PCT MOIST	ANGLE INTER FRICTION DEGREES AT 0.9 PCT MOIST
		0.75	10 IN DROP DEGREES AT 0.9 PCT MOIST	0.9 PCT MOIST	0.9 PCT MOIST	0.9 PCT MOIST
	2.59	36	36	34	215	106

GA-I CURRENT: I SEPT. 1972

46

KEY

SA
TUNNEL DATA

TUNNEL				VENTILATION			WATER INFLOW			UTILITY LINES			POWER SYSTEM	
SIZE 10FT X 10FT	SHAPE HORSESHOE	GRADE -0.22PCT	CFM AK	PRESS EXHAUST X	SIZE 22IN	HP	GPM	AIR 6IN	WATER 2IN	PUMP	PRIMARY 110V	SECONDARY		

HAULAGE SYSTEM

MUCK EIMCO 912 LHD DIESEL	PERSONNEL NONE	SUPPLY EIMCO 912 LHD DIESEL	HOLD TYPE SIZE 1IN X 7FT ROUTED APPROX 35FT	ROOF PLATE	SET SIZE SHAPE 4IN W STEEL SETS AT 4FT. APPROX. 160FT	SHOTCRETE

MACHINE EXCAVATION

MACHINE MAKE	MODEL	WT	CUTTERS, MAKE, TYPE, DIAM, CUTTING EGES CENTER	INTERIOR	GAGE	RPM	HEAD, CENTER	HEAD	THROTTLE, THROTTLE, THROTTLE KFTLB	TORQUE, MAX/OPERATE KFTLB	THROTTLE, MAX/OPERATE KFTLB	THROTTLE, MAX/OPERATE KFTLB

ANCHOR PRESS MUCK SYSTEM

ANCHOR PRESS KLR	MUCK SYSTEM	POWER SYSTEM	DISTANCE 100 FT	THROTTLE, THROTTLE, THROTTLE KFTLB

CONVENTIONAL EXCAVATION

MACHINE JUMBO CRAWLER MACHINES 2-93 DRIFTER	ROUND, NO. HOLES 48 DEPTH 8FT DIAM. 1-3/4 IN CUT. DOUBLE V FEED LENGTH 10FT	EXPLOSIVES, PODDER FACTOR 6.1LB/CY TOTAL LBS 175 GELEX 2, 70PCT PRIMERS, TRIM INTERIOR CUT LIFTERS	BLASTING ELECTRICAL 0-10 REGULAR DELAYS	HUCKING EIMCO 912 LHD FRONT END LOADER	GUIDANCE EIMCO 912 LHD TRANSIT

KEY IDENTIFICATION
6 HUNTER
SAMPLE NO H-1

ROCK PROPERTIES
IGNEOUS: GRANITE. GRAY. FINE
GRAINED, MODERATELY JUINED,
WITH 1.5 TO 2 FT BANDS OF
LIGHT TAN PEGMATITE AND
LAMINATED GRANITIC GNEISS.

MUCK DATA	DRY UNIT WT	MOISTURE PCF	PCT	IN.SIZE	PER CENT HY 6IN.	WEIGHT 3IN.	BETWEEN SCREENS 1/2IN.	NO4	NO8	NO16	NO30	NO100	NO200	PCT (-)
107	3.4	14.2	6.6	12.7	13.2	13.6	12.9	5.7	4.3	4.1	3.0	3.6	2.2	3.4

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDEO P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

A I A I A I A I A I A I A I

POT VOL CHANGE (-)0.056	IN.SIZE	Liquid LIMIT PCT	Plastic LIMIT PCT	Shrinkage Limit PCT	Size (-)0.056IN. 0.056IN.	Plasticity Index PCT	Flow Index PCT	Toughness Index PCT	SIZE (-)2.0 IN.
0	18.0	17.0	13.4	1.0	4.6	0.23			
(-)0.75 IN.SIZE SPECIF GRAVITY	ANGLE/RPOSE 1 IN DROP DEGREES AT 1.3 PCT MOIST	ANGLE/XPOSE 10' IN DROP 06DEGREES AT 1.3 PCI MOIST	MATERIAL SIZE (-)2.0 STEEL PLATE DEGREES AT 1.3 PCT MOIST	ANGLE/SLIDE DEGREES AT 1.3 PCT MOIST	APPARENT COHESION PSF AT PCT MOIST	BULK DENSITY PCF AT PCT MOIST			

2.70	40	37	32	NA	NA	44
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H-1 CURRENT: 1 SEPT. 1972

KEY

6A TUNNEL DATA

TUNNEL				VENTILATION			WATER INFLOW			UTILITY LINES			POWER SYSTEM	
SIZE	SHAPE	GRANE	CFM	PRESS	EXHST	X	SIZE	HP	GPM	AIR	WATER	PUMP	PRIMARY	SECONDARY
10FT X 10FT LOFT	HORSESHOE MODIFIED	+0.25PCT	15K				26IN	125	20-400	8IN	4IN	10IN	4160V	440V

HAULAGE SYSTEM

MUCK RAIL				PERSONNEL RAIL			SUPPLY RAIL			SUPPORT SYSTEM			SHOTCRETE		
MUCK RAIL	36IN GAGE	PERSONNEL RAIL	75LR RAIL	4.8 CY CARS	15TON LOCOMOTIVE				BOLT TYPE SIZE	ROOF PLATE	SET SIZE	SHOTCRETE SETS	SOOPSI 18 MRS	SOOPSI 28 DAYS	
									1IN X 7FT		4IN	4FT.	3FT. 2FT FOR 23PCT	16 PCT OF 7200 FT	

MACHINE EXCAVATION

MACHINE				CUTTERS, MAKE, TYPE, DIAM, CUTTING EDGES			POWER SYSTEM			GUIDANCE			THRUST/SQ FT		
MAKE	MODEL	WT	CENTER	INTERIOR	GAGE				HEAD, CENTER	HEAD			THRUST, MAX/OPENATE	THRUST, MAX OPERATE	
									KFTLB	KFTLB	KFTLB	KFTLB	KLB	KLB	

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
			KLB	

CONVENTIONAL EXCAVATION

MACHINE	ROUND, NO. HOLES	DEPTH	POWDER FACTOR	EXPLOSIVES	BLASTING	ELECTRICAL	MUCKING
JUMBO 4 BOOM HYDROJIB	38	10.5FT	5.5LBS/CY	POWDER	0-10 REGULAR	0-10 REGULAR	EIMCO NO25
MACHINES 4-CF99			TOTAL LBS 200	PHIMERS	DELAYS	DELAYS	RAIL, AIR
1-CF133			DIAM. 1-3/4 IN	GELEX 2-1 1/2 IN			OPERATED
FEED LENGTH 12FT			CUT. SPIRAL BURN	TRIM 20LB SMOOTHTEK 70PCY X 7/8IN			
			SIN CENTER HOLE	INTERIOR GELEX 2-1 1/2 IN			
			SF/HOLE 2.0	CUT GELEX 2-1 1/2 IN			
				LIFTERS GELEX 2-1 1/2 IN			

KEY IDENTIFICATION
? HUNTER
SAMPLE NO
H-2

ROCK PROPERTIES
igneous: granite gray.
gneissic, moderately jointed.

	DRY WT	MOISTURE PCT	PCF	IN. SIZE	PER CENT BY WEIGHT BETWEEN SCREENS	ORY WT PCF	COMPR STRNM KPSI	RQD PCT EST	SHORE MOH SCHMIDT
	164			6IN. 3IN. 2IN. 1IN. 1/2IN.	No4 No3 No2 No1	No30 No50 No100	No200	No200	PCT (-) NO200
109	3.4	7.3		11.7 18.2 19.3 11.6 9.3	4.8 4.2 4.5	3.4	1.3	NA	NA
									3.3

HUCK DATA
DRY UNIT WT PCF
MOISTURE PCT
PCF

PC(1+1)6
IN. SIZE
6IN. 3IN. 2IN. 1IN. 1/2IN.

PER CENT BY WEIGHT BETWEEN SCREENS

No4 No3 No2 No1

No30 No50 No100

No200

PCT (-)
NO200

109 3.4 7.3 11.7 18.2 19.3 11.6 9.3 4.8 4.2 4.5 3.4 1.3 1.1 3.3

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

A I A I A I A I A I A I A I

POT VOL CHANGE
(-)0.056 IN.SIZE
LIQUID LIMIT
PCT

ATTERBERG LIMITS..SIZE(-)0.056IN.
PLASTIC SHIMMAGE
LIMIT PCT

FLOW INDEX
PCT

TOUGHNESS
INDEX

18.10 17.95 11.00 0.15 3.20 0.04

(-)0.75 IN.SIZE
SPECIF GRAVITY

ANGLE/REPOSE
1 IN. CROP
DEGREES AT
3.8 PCT MOIST

MATERIAL SIZE(-)12.0 IN.
ANGLE/SLIDE
10 IN. DROP
DEGREES AT
3.8 PCT MOIST

APPARENT COHESION
PSF AT
2.6 PCT MOIST

BULK DENSITY
PCF AT
0.0 PCT MOIST

ANGLE INTER
FRICTION
DEGREES AT
2.6 PCT MOIST

SIZE(-)12.0 IN.
ANGLE INTER
FRICTION
DEGREES AT
2.6 PCT MOIST

105

44

2.60 3P 3S 38 30 105

H-2 CURRENT: 1 SEPT. 1972

KEY

7A
TUNNEL DATA

TUNNEL	VENTILATION				WATER INFLOW	UTILITY LINES	POWER SYSTEM
SIZE	SHAPE	GRADE	CFM	PRESS EXHST X	SIZE	HP	PRIMARY SECONDARY
10FT 10FT	HORSESHOE MONIFID	+0.25P+, I	8K		26IN	150	GPM 20-400
							AIR 8IN WATER 4IN PUMP 10IN
							4160V 480V

HAULAGE SYSTEM	PERSONNEL	SUPPLY RAIL	DOLT TYPE SIZE	ROOF PLATE	SET SIZE SHAPE	SHOTCRETE
MUCK RAIL • 36IN GAGE 75LB RAIL, 6.8 CY CARS, 1STON LOCOMOTIVE	RAIL		MINOR ROCK HOLE 1IN X 7FT			

MACHINE EXCAVATION

MACHINE	CUTTERS, MAKE, TYPE, DIAM.	CUTTING EDGES	RPM	THROTTLE, MAX/OPERATE
MAKE	MODEL	WT	HEAD CENTER	HEAD CENTER
			KFTLB KFTLB	KFTLB KFTLB
			KLB	KLB KLB

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
KLR				KLB

CONVENTIONAL EXCAVATION

MACHINE	BOOM HYDROJIB	ROUND	BLASTING	MUCKING
FEED LENGTH	4-6CF99 1-CF133	NO. HOLES 36-40 DEPTH 11FT DIAM. 1-1/4IN CUT. SPIRAL BURN 5IN CENTER HOLE SF/HOLE 2.6	ELECTRICAL 0-10 REGULAR DELAYS	EIMCO NO25 RAIL, AIR OPERATED

KEY IDENTIFICATION
8 LK
SAMPLE NO
LK-1

ROCK PROPERTIES
IGNEOUS. BIOTITIC QUARTZ
MONZONITE. FINE TO MEDIUM
GRAINED PORPHYRY.

DRY WT	WT PCF	COMPR STRNTH KPSI	RAD PCT EST	SHORE MOH	HARDNESS SCHMIDT
162	25	83	NA	NA	NA

MUCK DATA
DRY UNIT MOISTURE PCT(+)6 * * * * * PER CENT BY WEIGHT BETWEEN SCREENS * * * * *
WT PCF IN.SIZE 6IN. 3IN. 2IN. 1IN. 1/2IN. NO4 NO8 NO16 NO30 NO50 NO100 NO200 * * * * *
PCT (-) NO2000

102	0.4	66.8	13.8	5.9	5.0	3.8	2.0	0.7	0.5	0.4	0.3	0.3	0.1	0.4
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SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

A1 A1 A1 A1 A1 A1 A1 A1

POT VOL CHANGE * * * * * ATTERBERG LIMITS * * * * * SIZE (-) 0.056IN. PLASTICITY FLOW
(-)0.056 IN.SIZE LIQUID SHRINKAGE INDEX INDEX
LIMITS PCT PCT

0	16.10	17.98	17.69	0.12	3.90	0.30
---	-------	-------	-------	------	------	------

(-)0.75 IN.SIZE * * * * * MATERIAL SIZE (-)12.0 IN. APPARENT BULK
SPECIFIC ANGLE/REPPOSE ANGLE/SLIDE COHESION DENSITY
GRAVITY 1 IN DROP 10 IN DROP STEEL PLATE PCF AT
DEGREES A1 DEGREES AT DEGREES AT 0.4 PCT MOIST 0.0 PCT MOIST
0.8 PCT MOIST 0.8 PCT MOIST 0.4 PCT MOIST 0.4 PCT MOIST
0.4 PCT MOIST 0.4 PCT MOIST 0.4 PCT MOIST 0.4 PCT MOIST

2.85	33	30	29	435	97.3	43
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LK-1 CURRENT: - 1 SEPT. 1972

KEY

BA
TUNNEL DATA

TUNNEL	VENTILATION			WATER INFLOW			UTILITY LINES				
SIZE	SHAPE	GRADE	CFM	PRESS	EXHST	SIZE	HP	GPM	AIR	WATER	PUMP
15FT X 16FT	ARCHEO BACK	+5.5PCT	76K	HEAD	SURF	48IN	150	NONE	6IN	2IN	
HAULAGE SYSTEM											
HUCK WAGNER ST-B SCOOPTRAH. RAIL SKIP	PERSONNEL DIESEL TRUCK			SUPPLY DIESEL TRUCK		DOLT TYPE SIZE 3/4IN X 6FT AT 4FT		ROOF PLATE 13.5IN X 9FT	SET SIZE SHARE		SHOTCRETE

MACHINE EXCAVATION

MACHINE	CUTTERS, MAKE, TYPE, DIAM, CUTTING EDGES			RPM			TORQUE, MAX/OPERATE			THRUST, MAX/OPERATE		
MAKE	MODEL	WT	CENTER	INTERIOR	GAGE	HEAD	HEAD	CENTER	HEAD	CENTER	HEAD	HEAD
ANCHOR PRESS	MUCK SYSTEM					KFTLB	KFTLB	KFTLB	KFTLB	KFTLB	KFTLB	KFTLB
KLB												

CONVENTIONAL EXCAVATION

MACHINE	ROUND.	NO. HOLES	POWDER FACTOR	BLASTING
JUMAR 3 BOOM MACHINES GANISTER DENVER 1-PR123 2-DM123 DRIFTER CUT. FEED LENGTH 12FT	47	4.0	LBS/CY	ELECTRICAL
	DEPTH 10.5FT DIAM. 1-3/4IN 6 MOLE BURN 1-4IN CNTR HOLE SF/HOLE 5.4	365		0-15 REGULAR DELAYS
				LIFTERS ANFO

KEY 9 LK IDENTIFICATION
SAMPLE NO LK-2

ROCK PROPERTIES
IGNEOUS: BIOTITIC QUARTZ
MONzonite, FINE TO MEDIUM
GRAINED PORPHYR, WITH MINOR
STEEPLY INCLINED JOINS.

HARDNESS.....
SHORE MOH SCHMIDT

16S 28 83 NA NA NA

MUCK DATA
DRY UNIT MOISTURE PCT(1-16
WT PCF IN SIZE 6IN. *PER CENT BY WEIGHT BETWEEN SCREENS.....
PCF 3IN. 2IN. 1IN. 1/2IN. NO4 NO8 NO16 NO50 NO100 NO200
103 1.6 49.1 16.9 8.7 5.8 5.5 5.3 2.0 1.8 1.3 1.0 0.8 0.5 1.3

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDERO P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

AI AI AI AI AI AI AI

POT VOL CHANGE (-)0.05% IN SIZE
LIQUID PLASTIC SHINKAGE PLASTICITY FLOW
LIMIT LIMIT INDEX INDEX
PCT PCT PCT PCT
0 20.50 19.14 17.29 0.36 6.2 0.058

(-)0.75 IN SIZE ANGLE/REPOSE MATERIAL SIZE (-)2.0 IN..... APPARENT BULK
SPECIFIC GRAVITY 1 IN. DROP ANGLE/SLIDE COHESION COHESION
1 IN. DROP 10-IN UROP STEEL PLATE PSF AT PSF AT
DEGREES AT DEGREES AT 4.7 PCT MOIST 4.7 PCT MOIST 4.9 PCT MOIST 0.0 PCT MOIST 4.9 PCT MOIST
SIZE (-)2.0 IN.
ANGLE INTER
FRICTION
DEGREES AT
OEGRES AT
4.9 PCT MOIST 4.9 PCT MOIST 4.9 PCT MOIST

2.73 42 33 210 97.6 39

LK-2 CURRENT: 1 SEPT. 1972

KEY

9A TUNNEL DATA

TUNNEL				VENTILATION				WATER INFLOW				UTILITY LINES				POWER SYSTEM	
SIZE	SHAPE	GRADE	CFM	PRESS	EXHST	SIZE	HP	GPM	WATER	PUMP	PRIMARY	SECONDARY					
16FT X 16FT	ARCHD BACK	+2.00CT	22K	HEAD	SURF	48IN	150	NONE	AIR	WATER	4160V	220V					

HAULAGE SYSTEM

MUCK			PERSONNEL	SUPPLY	ROOF PLATE	SET SIZE, SHAPE	SHOTCRETE
WAGNER ST-8 SCOOTER, RAIL SKIP	DIESEL TRUCK	DIESEL TRUCK	3/4IN X 6FT AT 4FT	13.5IN X 9FT			

MACHINE EXCAVATION

MACHINE				CUTTERS, MAKE, TYPE, WIAM, CUTTING EDGES				TORQUE, MAX/OPERATE.				THRUST, MAX/OPERATE				
MAKE	MODEL	WT	CENTER	INTERIOR	GAGE	HEAD	CENTER	HEAD	HEAD	CENTER	KFTLB	KFTLB	KFTLB	KFTLB	KLB	KLB
ANCHOR	PRESS	MUCK SYSTEM		POWER SYSTEM	GUIDANCE	THRUST/SQ FT										

CONVENTIONAL EXCAVATION

MACHINE	JUMBO 3 EOLN MACHINES 3-PH123 DRIFTER	ROUND. NO. HOLES 47 DEPTH 10.5FT CUT. 6 HOLE BURN 1-4IN CNTR HOLE SF/HOLE 5.4	EXPLOSIVES, POWDER FACTOR 4LB/CY TOTAL LBS 365 PRIMERS, 25LB 1.5IN X 8IN, 60-75PCT TRIM 25LB 7/8IN X 16IN, 30PCT INTERIOR ANFO CUT 40LB 1.5IN X 15IN, 45PCT LIFTERS ANFO	BLASTING ELECTRICAL 0-15 REGULAR DELAYS	MUCKING SCOOTER	GUIDANCE LASER
---------	--	--	---	--	--------------------	-------------------

KEY IDENTIFICATION
10 LK
SAMPLE NO
LK-S

ROCK PROPERTIES
IGNEOUS: BIOTITIC QUARTZ
NONZONITE, FINE TO MEDIUM
GRAINED PORPHYRY

MUCK DATA
DRY UNIT MOISTURE PCT(+)6 IN.SIZE 6IN. 3IN. PER CENT BY WEIGHT BETWEEN SCREENS
WT PCF PCT IN. SIZE 1/2IN. 1IN. NO₄ NO₆ NO₁₆ NO₃₀ NO₅₀ NO₁₀₀ NO₂₀₀

16.8 0.0 0.0 0.0 13.0 14.0 20.0 7.0 8.0 8.0 6.0 5.0 11.0

POT VOL CHANGE (-)	0.056 IN.SIZE	LIQUID LIMIT PCT	PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	SIZE(-) 0.056IN.	PLASTICITY INDEX PCT	FLOW INDEX PCT	TOUGHNESS INDEX
0	25.00	20.95	19.68	4.05	0.50	0.73		

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUND P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

PE PI PI A A A A

ANGLE/REPOSE 1 IN. DROP DEGREES AT 3.4 PCT MOIST	MATERIAL SIZE (-)12.0 ANGLE/SLIDE 10 IN. DROP DEGREES AT 3.4 PCT MOIST	IN.	APPARENT COMESSION PSF AT 3.0 PCT MOIST	BULK DENSITY PCF AT 0.0 PCT MOIST	SIZE (-) 2.0 IN. ANGLE INTER FRICTION DEGREES AT 3.0 PCT MOIST
2.67	33	32	38	75	100
				37	

LK-S CURRENT: 1 SEPT. 1972

KEY

10A
TUNNEL DATA

TUNNEL	SHAPE	GRADE	VENTILATION	CFM	PRESS	EXHST	SIZE	HP	GPM	WATER INFLOW	UTILITY LINES	POWER SYSTEM
12FT 13-7/8IN PILOTMOLE	ROUND	VERT	NONE							NA	AIR	WATER PUMP 440V
MUCK WAGNER ST-8 SCOOTER RAIL SKIP	PERSONNEL DIESEL TRUCK											PRIMARY SECONDARY

Haulage System												
MUCK WAGNER ST-8 SCOOTER RAIL SKIP	PERSONNEL DIESEL TRUCK											

MACHINE EXCAVATION

MACHINE	MAKE	MODEL	WT	CENTER	CUTTERS, MAKE, TYPE, WIAM, CUTTING EDGES	RPM	FORWARD, MAX/OPERATE	THROTTLE, MAX/OPERATE
ROBBINS	ROBBINS	60IN RAISE 49 DRILL	49 TONS	11IN STL OISC-2-11IN	19 ROBBINS 12IN STEEL DISC-2-11 IN TWIN STEEL DISC	6 PIKES	HEAD, CENTER HEAD PIKES	KLB 814 KLB 490- 510

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
KLB	GRAVITY	ELECTRIC MOTORS 3-100 HP	SURFY IN PILOT HOLES	KLB 4.46

CONVENTIONAL EXCAVATION

MACHINE	ROUNDS, NO. MOLES DEPTH OIAM. CUT.	BLASTING	MUCKING	GUIDANCE
JUMBO MACHINES				
FEED LENGTH				
CUT LIFTERS				

IDENTIFICATION
LK 11
KEY
SAMPLE NO
LK-6

ROCK PROPERTIES
**IGNEOUS: BIOTITE
MONZONITE • FINE
GRAINED PORPHYRY
FLAT ANGLE JOIN**

ROD PCT EST
SHORE MOH SCHMIOT

PREPARATION.

MUCK DATA
DEGY UNIT
WT. PCF

0 16.8 0.0 0.0 0.0 1.0 9.0 19.0 12.0 11.0 11.0 6.0 7.0 6.0 16.0

0 16.8 0.0 0.0 0.0 1.0 9.0 19.0 12.0 11.0 11.0 0.0 7.0 6.0 16.0

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES

AI

*.....ATTENBERG LIMITS..SIZE(-) 0.056IN.....
LIQUID PLASTIC SHRINKAGE PLASTICITY FLOW TOUGHNESS
LIMIT LIMIT INDEX INDEX INDEX INDEX
PCT PCT PCT PCT

0 19-40 18-16 17-27 17-24 1-22

SPECIFIC GRAVITY	ANGLE/REPPOSE 1 IN. DROP	ANGLE/SLIDE DEGREES AT 3.7 PCT MOIST	SIZE (-) 0.75IN. SIZE	SIZE (-) 2.0 IN.		
				ANGLE/PLATE DEGREES AT 3.7 PCT MOIST	BULK COHESION PSF AT 0.2 PCT MOIST	ANGLE INTER FRICTION DEGREES AT 0.2 PCT MOIST
1.0	10	3.7	2.0	10	10	2.0

2.53 30 29 32 0 1.1 40

LK-6 CURRENT: 1 SEPT. 1972

KEY

TUNNEL DATA

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MACHINERY EXCAVATION

MACHINE	MAKE	MODEL	WT	CUTTERS, MAKE, TYPE, DIA., CUTTING EDGES	RPM	TORQUE, MAX/OPERATE	THRUST, MAX/OPERATE
ROBBINS	ROBBINS	H81R RAISE ORILL	49 TONS	CENTER 1 ROBBINS 12IN STEEL DISC INTERIOR 4 ROBBINS 12IN TWIN STEEL DISCS GAGE 1 ROBBINS 12IN TWIN STEEL DISCS	6 INTEG	HEAD CENTER KFTL8 583 KFTL8 260	KLB 220 KFTL8 260

B-22

CONVENTIONAL EXCAVATION

	BLASTING	HUCKING	GUIDANCE
ROUND.	EXPLOSIVES,		
NO. HOLES	POWDER FACTOR		
DEPTH	TOTAL LBS		
DIA.M.	PRIMERS.		
CUT.	TRIM		
	INTERIOR		
	CUT		
	LIFTERS		
MACHINE			
JUMBO			
MACHINES			
FEED LENGTH			

CURRENT: 09/01/72

LK-6

KEY IDENTIFICATION
12 LK

ROCK PROPERTIES
IGNEOUS: QUARTZ MONZONITE
PORPHYRY: INTENSELY ALTERED
COARSE GRAINED
SAMPLE NO
LK-7

DRY WT PCF	158
WET WT PCF	7
COMPR STRNTH KPSI	35
ROD PCT EST	NA
SHORE MOH HARDNESS	NA
SCHMIDT	NA

WUCY DATA	DRY UNIT MOISTURE	PCT(+)6 IN. SIZE	PER CENT HY WEIGHT BETWEEN SCREENS	NO8	NO16	NO30	NO50	NO100	NO200	PCT (-) ND200	
WT PCF	WT PCF	61 ^{1/2} , 3IN.	2IN. 1IN. 1/2IN.	NO4	NO8	NO16	NO30	NO50	NO100	NO200	
107	9.7	13.1	14.0 11.2 12.3	15.5	14.2	4.3	3.7	3.1	1.9	1.2	4.3

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUND P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

A A A A A A A A A

POT VOL CHANGE (-10.056 IN.SIZE	LIQUID LIMITS	PLASTIC LIMIT PCT	SMINKAGE LIMIT PCT	SIZE(-) 0.056IN.	PLASTICITY INDEX PCT	FLOW INDEX	TOUGHNESS INDEX
0	18.00	17.12	17.04	0.88	5.00	0.18	

(-)0.75 IN.SIZE	SPECIFIC GRAVITY	ANGLE/REPPOSE 1 IN. UROP	ANGLE/REPPOSE 10 IN UHOP	MATERIAL SIZE(-)2.0 IN.	APPARENT COHESION PSF AT 0.2 PCT MOIST	BULK OCF AT 0.2 PCT MOIST	SIZE(-) 2.0 IN. ANGLE INTER FRICITION DEGREES AT 0.2 PCT MOIST
2.68	2.9	2.6	2.8	70	114	45	7

LK-7 CURRENT: 1 SEPT. 1972

12A

124 TUNNEL DATA

TUNNEL	VENTILATION	WATER INFLOW	UTILITY LINES	POWER SYSTEM
SIZE 15FT X 14 FT	SHAPE ARCHEO BACK	GRADE -26PCT	CFM 22K	PRESS EXHST X
HULLAGE SYSTEM	PERSONNEL	SUPPLY DIESEL	AIR 6IN	WATER PUMP 2IN
MUCK WAGNER ST-B	DIESEL TRUCK	DIESEL TRUCK	4IN	4160 220
SCOOP TRAM			4IN	SECONDARY 220
RAIL SKIP				SHOTGUN EYE

MACHINE EXCAVATION

CONVENTIONAL CIRCUMSTANCES

GUIDANCE LASER
 BLASTING ELECTRICAL, 0-15 MPH/SEC DELAY
 EXPLOSIVES, POWDER FACTOR 4.7 LB/CY
 TOTAL LBS 350
 PRIMERS, 25LB, 1.54IN, 60PC
 TRIM 25LB, 7.8X16IN, 30PC
 INTERIOR CUT
 CUTTERS

KEY IDENTIFICATION
13 SH
SAMPLE NO
SH-1

ROCK PROPERTIES
IGNEOUS: QUARTZ
HORZONITE COURSE GRAINED
WITH MANY SULFIDE VENINETS
HIGHLY FRACTURED, DILATED
ORTHOGONAL FAULTING

ORY
WT
PCF
COMPR
STRNTH
KPSI
ROO
PCT
EST
SHORE
MOH
SCHEMIDT

MA

MUCK DATA
ORY UNIT
WT PCF
MOISTURE PCT (+) 6
IN. SIZE 6IN.
3IN. 2IN.
1IN. 1/2IN.
PER CENT MY WEIGHT BETWEEN SCREENS
NO4 NO3 NO2 NO1 NO0
PCT (-)
NO200

	97	1.1	21.5	10.8	3.7	14.8	17.0	14.0	5.9	3.0	2.6	1.5	0.7	0.7	2.2	
POT VOL CHANGE (-) 0.056 IN. SIZE																
LIQUID LIMIT PCT	0	12.50	11.02													
PLASTIC LIMIT PCT																
SHWINKAGE LIMIT PCT																
SIZE (-) 0.056 IN. ANGLE/REPOSE 1 IN. DROP DEGREES AT 0.2 PCT MOIST																

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=REGUNEOID P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

A A A A A A A A A

PLASTIC SHWINKAGE SIZE (-) 0.056 IN.
LIMIT PLASTIC SIZE (-) 0.056 IN.
INDEX INDEX
PCT PCT
FLOW INDEX
TOUGHNESS INDEX
PCT

	97	1.1	21.5	10.8	3.7	14.8	17.0	14.0	5.9	3.0	2.6	1.5	0.7	0.7	2.2	
POT VOL CHANGE (-) 0.056 IN. SIZE																
LIQUID LIMIT PCT	0	12.50	11.02													
PLASTIC LIMIT PCT																
SHWINKAGE LIMIT PCT																
SIZE (-) 0.056 IN. ANGLE/REPOSE 1 IN. DROP DEGREES AT 0.2 PCT MOIST																

MATERIAL SIZE (-) 12.0 IN.
ANGLE/REPOSE APPARENT BULK
1 IN. DROP STEEL PLATE DENSITY
DEGREES AT PSF AT PCT MOIST
0.2 PCT MOIST 0.0 PCT MOIST 0.2 PCT MOIST
SIZE (-) 2.0 IN.
ANGLE/INTER
FRICITION
DEGREES AT
0.2 PCT MOIST 0.2 PCT MOIST 0.2 PCT MOIST

	97	1.1	21.5	10.8	3.7	14.8	17.0	14.0	5.9	3.0	2.6	1.5	0.7	0.7	2.2	
POT VOL CHANGE (-) 0.056 IN. SIZE																
LIQUID LIMIT PCT	0	12.50	11.02													
PLASTIC LIMIT PCT																
SHWINKAGE LIMIT PCT																
SIZE (-) 0.056 IN. ANGLE/REPOSE 1 IN. DROP DEGREES AT 0.2 PCT MOIST																

SH-1 CURRENT: 1 SEPT. 1972

SH-1

KEY

13A
TUNNEL DATA

TUNNEL		VENTILATION			WATER INFLOW			UTILITY LINES			POWER SYSTEM	
SIZE	SHAPE	GRADE	CFM	PRESS EXHST	SIZE	MP	GPM	AIR	WATER	PUMP	PRIMARY	SECONDARY
12FT X 12FT	RECT	+0.4PCT	14K	X	24IN	60	None	4IN	2IN	BIN	2400	400
MUCK	PERSONNEL				SUPPORT SYSTEM							
RAIL 10 TON COTTON DUMP 36 IN GAGE 45 LB	RAIL				SUPPLY RAIL	GOLT, TYPE	SIZE	ROOF PLATE				

CONVENTIONAL EXCAVATION

MACHINE	MAKE	MODEL	WT	CENTER	INTERIC	GAGE		RPM	TOQUE, MAX/OPERATE	HEAD, CENTER	HEAD	THRUST, MAX/OPERATE
ANCHOR PRESS	MUCK SYSTEM						GUIDANCE	THRUST/SQ FT		KFTLB	KFTLB	KLB

CONVENTIONAL EXCAVATION

MACHINE: JUMBO 2 ROOM MACHINES CF79 QR O 89 FEED LENGTH 6 FT

NUMBER: NO. HOLEs: 52 DEPTH: 5 FT dia.: 1 1/2 IN cut: WEDGE

EXPLOSIVE: POWDER FACTOR 3.0, PREC TOTAL LBS: 100 PRIMERS, PRIMACORD TRIM AND CUT INTERIOR AND CUT ANGLES CUT ANGLES LIFTERS AND CUT

BLASTING: IGNITER CORD ETIMCO 40 LOADER FUSE: NO 6 C-25

HUCKING: ETIMCO 40 LOADER

GUIDANCE: TRANSIT

SK-1

CURRENT: 09/01/72

KEY IDENTIFICATION
14 CLIMAX
SAMPLE NO
CL-1

ROCK PROPERTIES
METAMORPHIC: GRANITIC GNEISS,
HIGHLY METAMORPHOSED,
MODERATELY TO HIGHLY
FRACTURED, HIGHLY SILICIFIED.

DRY
WT

MOISTURE
PCT

PCF

IN SIZE

PCT

KEY

I-4A
TUNNEL DATA

TUNNEL	VENTILATION	WATER INFLOW	UTILITY LINES				
SIZE 13FT	GRADE +0.25PCT	CFM 10K	PRESS EXHST X	SIZE 24IN	HP	GPM 5-10	AIR WATER PUMP 4IN 2IN
HAULAGE SYSTEM							
MUCK RAIL	PERSONNEL RAIL	SUPPLY RAIL	SUPPORT SYSTEM	BOLT TYPE SIZE	ROOF PLATE	SET SIZE SHAPE	SHOTCRETE

MACHINE EXCAVATION

MACHINE	CUTTERS, MAKE, TYPE, DIAM, CUTTING EDGES	RPM	TORQUE, MAX/OPERATE	THRUST, MAX/OPERATE			
MAKE CATERP. CALWELO	MODEL HARDROCK, 40	WT 200 TONS	INTERIOR 12" SMITH TCB TRICONE, 24IN	GAGE 6 SMITH TCB GTHMB ROLLER	HEAD CENTER 12' 26	HEAD CENTER KFTLB 347	KFTLB KFTLB KLB 133 KLB 130
ANCHOR PRESS							
KLB	BUCKET FROM FACE, CONVEYOR TO HEAR 24IN	POWER SYSTEM ELECTRO-HYDRAULIC 825 HP	GUIDANCE LASER	THRUST/SQ FT KLB 5.09			

CONVENTIONAL EXCAVATION

MACHINE	ROUNDS, NO. HOLES JUMBO MACHINES	BLASTING	HUCKING	GUIDANCE
FEED LENGTH	DEPTH OIAM, CUT.	EXPLOSIVES, POWER FACTOR TOTAL LBS PRIMERS, TRIM INTERIOR CUT LIFTERS		

KEY IDENTIFICATION
LK
SAMPLE NO
LK-3

ROCK PROPERTIES
METAMORPHIC: INTERLAYERED
TRANSITION BETWEEN QUARTZITE
AND TACTITE, MODERATELY TO
STRONGLY ALBITED METASEDIMENTS
WITH REPLACEMENT PYRITE.
CHALCOPYRITE AND MAGNETITE AND
A HIGH PERCENTAGE OF SILICATES
VERY FINE TO MEDIUM
GRAINED.

	MUCK DATA	DRY UNIT MOISTURE AT PCF	WET PCF	PCT (+) 16 IN. SIZE	6IN. 3IN. 2IN. 1IN. 1/2IN. NO4 NO8 NO16 NO30 NO50 NO100 NO200 NO200	PCT (-) NO200
105	0.1	34.1	17.4	9.1	10.2 10.6 8.7 2.8	1.6 1.2 0.8 0.4

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDERO P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SUPEREROID

A1 A1 A1 A1 A1 A1 A1

PCT VOL CHANGE (-) 0.05% IN. SIZE	LIQUID LIMITS PCF	PLASTIC LIMIT PCT	ATTERBERG LIMITS SHLINKAGE LIMIT PCT	SIZE (-) 0.056IN. 0.056 IN. ANGLE/REPOSE 1 IN. DROP DEGREES AT 1.5 PCT MOIST	0.056IN. 0.056 IN. ANGLE/SLIDE STEEL PLATE DEGREES AT 1.5 PCT MOIST	APPARENT COMENSION PSF AT 0.4 PCT MOIST	BULK DENSITY PCF AT 0.4 PCT MOIST	TOUGHNESS INDEX PCT	SIZE (-) 12.0 IN. 12.0 IN. ANGLE INNER FRICITION DEGREES AT 0.4 PCT MOIST
0	18.25	17.92	17.60	0.33	0.33	5.50	0.06		

(-)0.75 IN. SIZE
SPECIFIC
GRAVITY
ANGLE/REPOSE
1 IN. DROP
DEGREES AT
1.5 PCT MOIST

MATERIAL SIZE (-) 12.0 IN.
ANGLE/REPOSE
1 IN. DROP
DEGREES AT
1.5 PCT MOIST

ANGLE/SLIDE
STEEL PLATE
DEGREES AT
1.5 PCT MOIST

APPARENT
COMENSION
PSF AT
0.4 PCT MOIST

BULK
DENSITY
PCF AT
0.4 PCT MOIST

TOUGHNESS
INDEX
PCT

SIZE (-) 12.0 IN.
ANGLE INNER
FRICITION
DEGREES AT
0.4 PCT MOIST

3.21 30 29 29 175 117.8 41

LK-3 CURRENT: 1 SEPT. 1972

KEY

15A
TUNNEL DATA

TUNNEL				VENTILATION				WATER INFLOW				UTILITY LINES			
SIZE	SHAPE	GRADE	CFM	PRESS	EXHST	SIZE	HP	GPM	AIR	WATER	PUMP	PRIMARY	SECONDARY	4140V	220V
16FT X 14-1/2FT BACK	ARCHED	+2.0PCT	52K	HEAD SURF	48IN	150	None		6IN	2IN					
HAILAGE SYSTEM															
MUCK WAGNER ST-8 SCOOTER TRAIL. SHIP	PERSONNEL DIESEL TRUCK	SUPPLY DIESEL TRUCK	BOLT TYPE	SIZE 3/4IN X 6FT AT 4FT	ROOF PLATE 13.5IN X 9FT							SET SIZE SHAPE	SHOTCRETE		

MACHINE EXCAVATION

MACHINE				CUTTERS, MAKE, TYPE, DIAM, CUTTING EDGES				RPM				TORQUE, MAX/OPERATE CENTER				THRUST, MAX/OPERATE CENTER			
MAKE	MODEL	WT	CENTER	INTERIOR	GAGE	HEAD	HEAD	KFTLB	KFTLB	KFTLB	KFTLB	KLB	KLB	KLB	KLB				
ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM				GUIDANCE	THRUST/SQ FT												
		KLB																	

CONVENTIONAL EXCAVATION

MACHINE JUMBO 3 400M MACHINES 3-PRI23 DRIFTERS FEED LENGTH 12FT	ROUND, NO. HOLES 42 DEPTH 6FT DIAM. 1-3/4IN CUT, 6 HOLE BURN 1-4IN CHIN HOLE SF/HOLE 5.0	EXPLOSIVES, POWDER FACTOR 5LB/CY TOTAL LBS 205 PRIMERS, 15LR 1.5IN X 8IN, 60-75PCT TRIM 15LB 7/8IN X 16IN, 30PCT INTERIOR ANFO CUT 25LB 1.5IN X 16IN, 45PCT LIFTERS ANFO	BLASTING ELECTRICAL 0-15 REGULAR DELAYS	MUCKING SCOOPTRAH
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KEY IDENTIFICATION
LK
SAMPLE NO
LK-4

ROCK PROPERTIES
METAMORPHIC: TACTITE STRONGLY
ALTERED CALCAREOUS META-
SEDIMENTS, WITH REPLACEMENT
PYRITE, CHALCOPYRITE AND
MAGNETITE AND A HIGH PER-
CENTAGE OF SILICAIFERS, FINE TO
VERY FINE GRAINED.

HUCK DATA DRY UNIT WT PCF	MOISTURE PCF	PCT(%) IN. SIZE 5IN. 3IN. 2IN. 1IN. 1/2IN.	PER CENT BY WEIGHT BETWEEN SCREENS						NO16 NO8 NO4	NO30 NO50	NO100 NO200	PCT (%) NO200	
			124	2.1	26.3	19.3	13.7	13.9	9.8	7.3	1.6	1.2	0.8
													2.9

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SURANGULAR R=ROUNDERO P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

A I A I A I A I A I A I A I A I

POT VOL CHANGE (-)0.056 IN.SIZE	LIQUID LIMIT PCT	ATTERBERG LIMITS (-) 0.056 IN.						PLASTIC LIMIT PCT	FLOW INDEX PCT	TOUGHNESS INDEX
		A	I	S	P	C	R			
0	19.00	17.95	16.43	1.05	5.40	0.19				

(-) 0.75IN.SIZE * ANGLE/REPOSE
SPECIFIC GRAVITY
ANGLE/REPOSE
1 IN DROP
DEGREES AT
2.0 PCT MOIST

MATERIAL SIZE (-) 2.0 IN.
ANGLE/REPOSE
10 IN DROP
DEGREES AT
2.0 PCT MOIST

ANGLE/SLOPE
STEEL PLATE
DEGREES AT
2.0 PCT MOIST

APPARENT COMESSION
PSF AT
0.2 PCT MOIST 0.0 PCT MOIST

BULK DENSITY
PCF AT
0.2 PCT MOIST 0.0 PCT MOIST

SIZE (-) 2.0 IN.
ANGLE INTER
FRICTION
DEGREES AT
0.2 PCT MOIST

3.36	37	35	30	165	115	43

LK-4 CURRENT: 1 SEPT. 1972

KEY

164 TUNNEL DATA

HAULAGE SYSTEM		VENTILATION		WATER INFLOW		UTILITY LINES		POWER SYSTEM	
MUCK		GRADE		PRESSURE		AIR		PRIMARY	
WAGNER ST-8		CFH		EXHAUST		WATER		SECONDARY	
SCOOTER		50K		HEAD		PUMP		4160V	
RAIL		SURF		6IN		6IN		220V	
SHAPE		SIZE		HP		2IN		SHOTCRETE	
ARCHED		+2.0PCFT		GPM		NET+SISE+SHAPE		WITH NF STEEL SETS	
BACK		15FT X		150		AT 5FT		AT 5FT	
14F:									
SUPPORT SYSTEM		SUPPLY		dOLT TYPE SIZE		ROOF PLATE			
PERSONNEL		O1ESEL		NONE					
O1ESEL		TRUCK							

MACHINE EXCAVATION

ANCHOR PRESS	HUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT	KN/FT
MACHINE	CUTTERS, MAKE, TYPE, U.I.A., CUTTING EDGES				
MAKE	MODEL	WT	CENTER	INTERIOR	GAGE

CONVENTIONAL EXCAVATION

MACHINE	ROUNO.	GUIDANCE
JUMBO 3 ROOM MACHINES	NG - MOLES 42 DEPTH 6 FT	LASER
GARDNER DENVER 3-PR123 DRIFTERS	01M. 1-3/4 IN CUT, 6 HOLE BURN 1-4 IN CENTER HOLE SF/HOLE 4.4	NUCKING SCOOPTAN
FEED LENGTH 12FT		BLASTING ELECTRICAL DELAYS
		POWDER FACTOR 5.5LB/CY
		TOTAL LBS 205
		PRIMERS, 15LB 1.5IN X 8IN, 60-75PCT
		TRIM 15LB 7.5IN X 16IN, 30PCT
		INTERIOR ANFO
		CUT 25LB 1.5IN X 16IN, 45PCT
		LIFTERS ANFO

KEY IDENTIFICATION
17 MATHER B
SAMPLE NO
4B-1

ROCK PROPERTIES
METAMORPHIC: INTER LAYERED
BANDS HEMATITE AND MARTITE
HIGHLY JOINTED, NORMALLY FLAT
LYING, OFTEN HIGHLY FOLDED.
NATURAL IRON OVER 60 PCT
MOISTURE 9 PCT, SILICA 5 PCT.

	DRY WT	COMPR STRN IN KPSI	ROD PCT EST	HARDNESS.....
MUCK DATA	MOISTURE PCT	PT(+)6 IN. SIZE	PER CENT BY WEIGHT BETWEEN SCREENS	SHORE MOH SCHMIOT
	WT PCF	6IN. 3IN. 2IN. 1IN.	No4 No8 No16 No30 No50 No100	No200
128	7.2	9.7	1.4 8.7 11.4 20.1 10.3 7.4 3.3	1.6 1.3 1.1

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES

A=ANGULAR S=SUBANGULAR R=ROUNDEO P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

AI AI AI AI AI AI AI AI

POT VOL CHANGE (-)-0.056 IN.SIZE	Liquid LIMIT PCT	PLASTIC LIMIT PCT	ATTENBERG LIMITS..SIZE (-) 0.056IN.	PLASTICITY INDEX PCT	FLOW INDEX PCT	TOUGHNESS INDEX PCT
0	17.8	15.1	13.9	2.1	4.1	0.66

(-)-0.75 IN.SIZE SPECIF GRAVITY	ANGLE/REPSE 1 IN DROP DEGREES AT 6.2 PCT MOIST	MATERIAL SIZE(-)12.0 ANGLE/REPSE 10 IN UROP DEGREES AT 6.2 PCT MOIST	APPARENT COHESION STEEL PLATE DEGREES AT 6.2 PCT MOIST	BULK DENSITY PSF AT 6.9 PCT MOIST	ANGLE INTER FRICTION DEGREES AT 6.9 PCT MOIST	SIZE(-)2.0 IN. ANGLE INTER FRICTION DEGREES AT 6.9 PCT MOIST
4.34	37	35	31	235	141	35

KEY

17A
TUNNEL DATA

TUNNEL						VENTILATION			WATER INFLOW			UTILITY LINES			POWER SYSTEM	
SIZE 9FT 11.5IN	SHAPE ROUND	GRADE 0.0	CFM 3K	PRESS X	EXIST	SIZE 8IN	HP 5	GPM NONE	AIR 2IN	WATER 1IN	PUMP	PRIMARY	SECONDARY	440V		
HAULAGE SYSTEM																
MUCK 42IN SCRAPER		PERSONNEL RAIL MOIST		SUPPLY RAIL MOIST		SUPPORT SYSTEM	BOLT-TYPE SIZE	ROOF PLATE	SET-SIZE-SHAPE 9FT 6IN DIA. X 4IN WF AT 45IN		SHOTCRETE					

MACHINE EXCAVATION

MACHINE			CUTTERS, MAKE, TYPE, DIAM., CUTTING EGGS			RPM			TORQUE, MAX/OPERATE			THRUST, MAX/OPERATE			
MAKE CALFIELD	MODEL OCCILLATOR	WT 69 TONS	CENTER	INTERIOR 2>8 CARBOLOGY DRAG BITS	GAGE 20 CARBOLLOY RIPPERS	HEAD-CENTER 8	HEAD	HEAD	HEAD	HEAD	HEAD	HEAD	HEAD	HEAD	
ANCHOR PRESS KLB 285	MUCK SYSTEM FLIGHT CONVEYOR TO REAR OF MACHINE	POWER SYSTEM REMOTE HYDRAULIC PUMPS, 2-90GPM, 2500 PSI, 2-125 HP MOTORS	GUIDANCE SURVEY	THRUST/SQ FT KLB 3.66											
CONVENTIONAL EXCAVATION															
MACHINE JUMBO MACHINES	ROUND, NO. HOLES DEPTH DIAM. CUT.	EXPLOSIVES, POWDER FACTOR TOTAL LBS PRIMERS, TRIM INTERIOR CUT LIFTERS	BLASTING	MUCKING	GUIDANCE										
FEED LENGTH															

KEY IDENTIFICATION
18 MB
SAMPLE NO
MH-3

ROCK PROPERTIES
METAMORPHIC: INTERLAYERED
HEMATITE AND MARTITE
HIGHLY JOINTED, NORMALLY
FLAT LYING, OFTEN HIGHLY
FOLDED, NATURAL IRON
60 0/0, SILICA 5 0/0

MUCK DATA
DRY UNIT MOISTURE PCT (+) 6 * * * * PER CENT BY WEIGHT BETWEEN SCREENS
WT PCF IN.SIZE 6IN. 3IN. 2IN. 1IN. 1/2IN. NO4 NO8 NO16 NO30 NO50 NO100 NO200
PCT (-) NO200

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDING P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

POT VOL CHANGE
(-) IN.SIZE
LIQUID LIMIT
PCT
PLASTIC LIMIT
PCT
SHRINKAGE LIMIT
PCT
SIZE (-)
ATTERBERG SIZE (-)
PLASTIC INDEX
INDEX
FLOW INDEX
TOUGHNESS INDEX

(-) IN.SIZE
SPECIFIC GRAVITY
ANGLE/REPOSE
1 IN. DROP
DEGREES AT
DEGREES AT
PCT MOIST
MATERIAL SIZE (-)
ANGLE/REPOSE
10 IN. UROP
DEGREES AT
PCT MOIST
ANGLE/SLIDE
STEEL PLATE
DEGREES AT
PCT MOIST
APPARENT COHESION
PSF AT
PCT MOIST
BULK DENSITY
PCF AT
PCT MOIST
SIZE (-)
ANGLE INTER
FRICTION
DEGREES AT
PCT MOIST

CURRENT: 1 SEPT. 1972.

KEY

TUNNEL DATA

TUNNEL	VENTILATION	WATER INFLOW	UTILITY LINES							
SIZE	GRADE	CFM	PRESS	EXHST	SIZE	MP	GPM	AIR	WATER	PUMP
10FT X 9FT 6 IN	0	4K	X		1IN	IS	NONE	2IN	1IN	
HAULAGE SYSTEM										
MUCK 48IN SCRAPER 160 CF CARS 2-30T MOTORS 30 IN GAGE COU3 RAIL	PERSONNEL RAIL	SUPPLY RAIL	dOLT.	TYPE	SIZE	ROOF PLATE	SET, SIZE, SHAPE BINNSHLB WF SETS 7FT CAP, 8FT POSTS WOOD LAGGING PIPE SPILING 8-1IN DIA-6-2IN DIA			SHOTCRETE

MACHINE EXCAVATION

MACHINE	CUTTERS, MAKE, TYPE, WIAM, CUTTING EDGES	RPM	THROTTLE, MAX/OPERATE
MAKE	MODEL	HEAD, CENTER	HEAD
ALPINE	F-6A	WT 11T	60
		CENTER 68 KENNAMETAL ON TWIN RIPPER HEADS	KFTLB49 KFTLB KFTLB KFTLB
ANCHOR PRESS	MUCK SYSTEM GATHERING ARMS, FLIGHT CONVEYORS	POWER SYSTEM 440V	GUIDANCE TRANSIT KLH

CONVENTIONAL EXCAVATION

MACHINE	ROUND, NO. HOLES DEPTH DIAM. CUT,	EXPLOSIVES, POWDER FACTOR TOTAL LBS PRIMERS, TRIM INTERIOR CUT LIFTERS	BLASTING	MUCKING	GUIDANCE
JUMBO MACHINES FEED LENGTH					

	ROCK PROPERTIES	COMPR STRENGTH KPSI	ROC	••••• MARIONESS •••••
KEY 19	METAMORPHIC: QUARTZITE. MEDIUM TO THIN BEDDED. MODERATELY TO HIGHLY FOLDED. MODERATE FRACTURING	DRY WT PCF	PCT TST	SHORE F-24 SCHMIDT
SAMPLE NO ST-1			NA	NA
			75	NA

PCT (-)
NO260
NO200
NO100
N050
N030
N015
N004
N003
N002
N001

A=ANGULAR S=SUBANGULAR R=ROUNDERO P=PLATY C=CUBIC I=IRREGULAR F=ELONGATED SP=SPPHEROID

POT VOL CHANGE (-) IN SIZE (-) ATTBERG LIMITS (-) SIZE (-) LIQUID PLASTIC SHRINKAGE PLASTICITY FLOW INDEX TOUGHNESS INDEX
LIMITS PCT LIMIT INDEX PCT PCT

ST-1 CURRENT: 1 SEPT. 1972

KEY

19A
TUNNEL DATA

TUNNEL				VENTILATION			WATER INFLOW			UTILITY LINES			POWER SYSTEM	
SIZE 5FT X 10 FT 1.5IN	SHAPE ARCH BACK	GRADE +0.5PCT	CFM 7	PRESS X	EXHST	SIZE 24 IN	HP 40	GPM NONE	AIR 4 IN	WATER 2 IN	PUMP	PRIMARY 2300	SECONDARY 480	
HAULAGE SYSTEM														
MUCK 60 CF 40 LB RAIL	SIDE DUMP RAIL	PERSONNEL	SUPPLY RAIL	BOLT 6FT X .75IN 4/ MAT	TYPE ROOF PLATE .75IN 21 BACK, 21 EACH RIB	SIZE 9FT X 3IN HATS	ROOF PLATE .75IN 21 BACK, 21 EACH RIB	SHOTCRETE						
24 IN GAGE 6 T MOTOR														

MACHINE EXCAVATION

MACHINE				CUTTERS, MAKE, TYPE, DIAM, CUTTING EDGES			GUIDANCE			TORQUE, MAX/OPERATE			THRUST, MAX/OPERATE	
MAKE	MODEL	WT	CENTER	INTERIOR	GAGE	HEAD	CENTER	HEAD	CENTER	HEAD	CENTER	KFT/LB	KFT/LB	
ANCHOR PRESS	MUCK SYSTEM	WT	center	interior	gage	head	center	head	center	head	center	KFT/LB	KFT/LB	
		KLB			KLB									

CONVENTIONAL EXCAVATION

MACHINE JUMBO 3 BOOM MACHINES 2-583F 1-D99 FEED LENGTH 8FT	ROUND, NO. HOLES 44 DEPTH 7 FT DIAM. 1 5/8 IN CUT. BURN2-4 IN	EXPLOSIVES, POWER FACTOR 5.4LB/CY TOTAL LBS 125 PRIMERS, 25LBS 60HR HANG IN TRIM NILLITE INTERIOR NILLITE CUT NILLITE LIFTERS NILLITE	BLASTING ELECTRICAL 0-14 REGULAR DELAYS	MUCKING ATLAS-COPCO LM56	GUIDANCE TRANSIT
---	---	--	--	--------------------------------	---------------------

KEY	IDENTIFICATION CR	ROCK PROPERTIES			DRY WT PCF	CDMPR STRENGTH KPSI	ROD PCT EST	SHORE MOH SCHEMIDT
		METAMORPHIC: QUARTZITE	Moderately folded	Moderately to highly fractured				
20	SAMPLE NO CR-1	/JOINED WITH MINOR FILLED VEINLETS, DIPPING 75-90 DEGREES	NA	NA	50	NA	NA	NA
MUCK DATA	DRY UNIT WT PCF	MOISTURE PCT	PCT+16 IN SIZE 6IN.	*.....PER CENT BY WEIGHT BETWEEN SCREENS.....*	ND16	ND30	NO100	PCT (-) ND200
			3IN. 2IN. 1IN. 1/2IN.	ND4	NO8	ND30	NO100	ND200

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SQUARE R=ROUND P=PLATE C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

20T VUL CHANGE (-)	IN SIZE	ATTERBERG LIMITS (-)			IN SHRINKAGE LIMIT PCT	PLASTICITY INDEX PCT	FLDW INDEX PCT	TOUGHNESS INDEX
		Liquid	Plastic	Limit				
		PCT	PCT	PCT				

(-)	SPECIFIC GRAVITY	IN SIZE	ANGLE/REPOSE 1 IN DROP DEGREES AT PCT MOIST	MATERIAL SIZE (-) ANGLE/REPOSE 10 IN DROP DEGREES AT PCT MOIST	IN ANGLE/SLIDE STEEL PLATE DEGREES AT PCT MOIST	APPARENT COHESION PSF AT PCT MOIST	BULK DENSITY PCF AT PCT MOIST	SIZE (-) ANGLE INTER IN. FRICTION DEGREES AT PCT MOIST

CR-1 CURRENT: 1 SEPT. 1972

KEY
20A TUNNEL D

20A
TUNNEL DATA

MACHINERY EXCAVATION

CONVENTIONAL EXCAVATION

KEY	IDENTIFICATION	ROCK PROPERTIES			DRY WT PCF	COMPRESSIVE STRENGTH KPSI	REO PCT EST	HARDNESS SHORE MOH	SCHMIDT					
21	HOMESTAKE	METAMORPHIC: PHYLLOLITE WITH VEIN QUARTZ. CHLORITE SCHIST HIGHLY METAMORPHOSED AND FOLDED. WITH MINOR FAULTING												
	SAMPLE NO				187	19	70		NA					
MUCK DATA	DRY UNIT WT	MOISTURE PCT	PCT (16 IN.SIZE)	PER CENT BY WEIGHT 6 IN. 3 IN. 1 IN. 1/2 IN.	NO4	BETWEEN SCREENS..... NO8 NO16 NO30 NO50	NO100	NO200	PCT (-) NO200					
1.36	2.2	25.3	1.5	9.2	13.2	13.3	10.4	3.2	2.0	1.2	0.7	0.5	0.5	3.0

SHAPE OF FRACTION BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDERO P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

P	A	P	A	P	A	P	A	A
---	---	---	---	---	---	---	---	---

POT VOL CHANGE (-0.056 IN.SIZE	LIQUID LIMIT PCT	PLASTIC LIMIT PCT	SMINKEAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX PCT	TOUGHNESS INDEX
0	19.80	16.06	15.12	2.74	2.70	1.01

(-10.75 IN.SIZE	SPECIFIC GRAVITY	MATERIAL SIZE (-)2.0 ANGLE/REPOSE 1 IN DIA DEGREES AT 3.1 PCT MOIST	ANGLE/REPOSE 10 IN DIA DEGREES AT 3.1 PCT MOIST	STEEL PLATE DEGREES AT 3.1 PCT MOIST	APPARENT COMPRESSION PSF AT 2.0 PCT MOIST	BULK DENSITY PSF AT 2.0 PCT MOIST	SIZE (-)2.0 IN. ANGLE INTER FRICTION DEGREES AT 2.0 PCT MOIST
2.84	4.0	34	31	160	99	39	

MS-1 CURRENT: 1 SEPT. 1972

KEY

21A
TUNNEL DATA

TUNNEL				VENTILATION				WATER INFLOW				UTILITY LINES				POWER SYSTEM			
SIZE 7FT6IN	SHAPE ARCH	GRADE BACK:	CFM 7K	PRESS EXHST X	SIZE 16 IN 30	HP MINOR	GPM	AIR 2 IN 2 IN	WATER PUMP	PRIMARY 2400	SECONDARY 440								
HAULAGE SYSTEM																			
MUCK RAIL	PERSONNEL RAIL	SUPPLY RAIL		BOLT TYPE SIZE 6 FT X 5/8 IN	ROOF PLATE		SET SIZE SHAPE						SHOTCRETE						
1.5T ROLLER CARS 40LB RAIL 18 IN GAGE 6 OR 8 T MOTORS																			

MACHINE EXCAVATION

MACHINE				CUTTERS, MAKE, TYPE, DIAM, CUTTING EDGES				POWER SYSTEM				TORQUE MAX/OPERATE				THRUST MAX/OPERATE			
MAKE	MODEL	WT	CENTER	INTERIOR	GAGE			HEAD	HEAD	HEAD	HEAD	KFTLB	KFTLB	KFTLB	KFTLB	KLB	KLB		
ANCHOR PRESS	MUCK SYSTEM							GUIDANCE	THRUST/SQ FT										
KLB								KLB											

CONVENTIONAL EXCAVATION

MACHINE	JUMBO AIR LEG	NO. HOLES	30	EXPLOSIVES	POWDER FACTOR	7.0 LB/CY	BLASTING	MUCKING
MACHINES 3IN JACK HAMMER	HAMMER DEPTH	18 FT		TOTAL LBS	140		ELECTRICAL	EIMCO
DIAM.	1.5 IN			PRIMERS	.4LB.	7' MILE SECOND	7' MILE	21
CUT.	1.5 IN			TRIM ANFO		0-REGUL-AR		
FEED LENGTH	6FT			INTERIOR ANFO				
				CUT ANFO				
				LIFTERS ANFO				

KEY IDENTIFICATION
22 NEW YORK
SAMPLE NO
NY-1

ROCK PROPERTIES
METAMORPHIC: MICA SCHIST
OCCASIONAL QUARTZ
LAMINATIONS

	DRY UNIT WT	MOISTURE PCF	PCF IN.SIZE	PER CENT BY 6IN. 3IN. 2IN. 1IN. 1/2IN.	N04	N08	N016	N030	N050	N0100	N0200	PCT (-)
	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

MUCK DATA
DRY UNIT MOISTURE PCF (+) 6 IN.SIZE
WT PCF IN. 3IN. 2IN. 1IN. 1/2IN.
101 12.4 0 0 0 3.5 21.9 12.3 6.6 7.5 5.3 7.5 11.7 7.7 16.0

SHAPE OF FRACTION BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

PAI PA PA AI A-P A

POT VOL CHANGE
(-) IN.SIZE
LIQUID PLASTIC LIMIT
PCT
ATTERBERG LIMITS
PCT
SIZE (-)
SMINKEAGE
LIMIT
PCT
PLASTICITY
INDEX
FLOW
INDEX
TOUGHNESS
INDEX

(-) IN SIZE * MATERIAL SIZE (-) IN APPARENT ANGLE/REPOSE
SPECIF GRAVITY I IN DRUP 10 IN DRUP COHESION STEEL PLATE
DEGREES AT DEGREES AT DEGREES AT PSF AT PCT MOIST PCT MOIST
PCT MOIST PCT MOIST PCT MOIST
SIZE (-) IN.
ANGLE INTER IN.
FRICITION
DEGREES AT
PCT MOIST PCT MOIST
PCT MOIST

NY-1 CURRENT 1 SEPT. 1972

KEY

22A
TUNNEL DATA

TUNNEL				VENTILATION				WATER INFLOW				UTILITY LINES				POWER SYSTEM			
SIZE 11 FT 6 IN	SHAPE ROUND	GRADE -0.03%CT	CFM 36K	PRESS EXHST	SIZE X	H.P. 40	GPM 40	AIR 4 IN	WATER 4 IN	PUMP 6 IN	PRIMARY 6600	SECONDARY 440							
HAULAGE SYSTEM																			
MUCK RAIL	PERSONNEL RAIL			SUPPLY RAIL				SUPPORT SYSTEM	BOLT TYPE SIZE	ROOF PLATE									
17CY CAPS								SET SIZE SHAPE	HALF CIRCLE										
10T MOTORS								BOLTED STEEL											
70LB RAIL								LAGGING IN											
36 IN GAGE								FAULT ZONES											

MACHINE EXCAVATION

MACHINE				CUTTERS, MAKE, TYPE, DIAM, CUTTING EDGES				RPM				TORQUE, MAX/OPERATE				THRUST, MAX/OPERATE			
MAKE	MODEL	WT	CENTER	INTERIOR	GAGE	HEAD, CENTER	HEAD	HEAD, CENTER	HEAD	HEAD	HEAD	HEAD	HEAD	HEAD	HEAD	HEAD	HEAD		
JARVA	12-112	WT NA	2 REED NA	20 REED, 3 DISC NA	6 JARVA TC6 DISC, OKC-3W OK-1	KFTLBN	KFTLBS	KFTLBS	KFTLBS	KFTLBS	KFTLBS	KFTLBS	KFTLBS	KFTLBS	KFTLBS	KFTLBS	KFTLBS		

ANCHOR PRESS K.LB	MUCK SYSTEM BUCKETS TO BELT	POWER SYSTEM NA	GUIDANCE LASER	THRUST/SQ FT KLB

CONVENTIONAL EXCAVATION

MACHINE JUMBO MACHINES	ROUND, NO. HOLES DEPTH, DIAM. CUT,	BLASTING	HUCKING	GUIDANCE
FEED LENGTH				

				HARNESS	
				SHORE	MOM SCHMIOT
			ROD	PCT	
			EST		
					NA
KEY	IDENTIFICATION	ROCK PROPERTIES	COMPR	RD	NA
23	NEW YORK	METAMORPHIC: MICA SCHIST	WT	PCT	90
	SAMPLE NO	OCASSIONAL QUARTZ	KPSI	EST	
	NY-2	LAMINATIONS			

97 7.2 0 0 0 2.2 13.3 10.6 5.0 9.2 6.5 9.1 14.6 9.5 19.0

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR B=SUBANGULAR C=CUBIC D=ROUND E=IRREGULAR F=ELONGATED SP=SPHEROID

B-45

POT VOL CHANGE (-)	IN. SIZE	LIQUID LIMITS PCT	PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	SIZE(-) IN.	PLASTICITY INDEX	FLOW INDEX	TOUGHNESS INDEX
+	*	ALTERING LIMITS..	ALTERING LIMITS..	ALTERING LIMITS..	-	-	-	-

NY-2 CURRENT: 1 SEPT. 1973

KEY

23A
TUNNEL DATA

TUNNEL	SHAPE	GRADE +0.03PCT	CFM 18K	PRESS EXHST	SIZE 12 IN	HP 4.0	WATER INFLOW	UTILITY LINES	POWER SYSTEM
SIZE 8 FT 6 IN	ROUND						AIR 4 IN	WATER 4 IN	PUMP 4 IN
HAULAGE SYSTEM									
MUCK RAIL	PERSONNEL RAIL		SUPPLY RAIL		BOLT•TYPE SIZE	ROOF PLATE	SET•SIZE•SHAPE HALF CIRCLE BOLTED STEEL LAGGING IN FAULT ZONES		SHOTCRETE
13 CY CARS 10 T MOTORS 70 LR RAIL 36 IN GAGE									
MACHINE EXCAVATION									
MACHINE MAKE	MODEL JARVA	WT NA	WT NA	CENTER 2 REED TOOTH TYPE	INTERIOR 12 REED QC-3 TCB BUTTON	GAGE QC-3W• TCB	RPM HEAD•CENTER NA	TORQUE•MAX/OPERATE HEAD KFTLBNA KFTLB	THRUST•MAX/OPERATE CENTER KFTLB KFTLB
KLB	6-806								
ANCHOR PRESS	MUCK SYSTEM BUCKETS TO BELT		POWER SYSTEM NA		GUIDANCE LASER	THRUST/SQ FT KLB			
KLB									
CONVENTIONAL EXCAVATION									
MACHINE JUMBO MACHINES		ROUND• NO. HOLES DEPTH MACHINES				EXPLOSIVES, TOTAL LBS PRIMERS, TRIM INTERIOR CUT LIFTERS	BLASTING	MUCKING	GUIDANCE
FEEO LENGTH		DEPTH CUT,							

KEY IDENTIFICATION
24 QUEEN LANE
SAMPLE NO QL-1

ROCK PROPERTIES
METAMORPHIC: GRAY MICA SCHIST
OCCASIONAL QUARTZ SEAMS. MICA
VARIES FROM DENSE. FINE
GRAINED TO EXTREMELY COARSE.

165

II

30

NA

NA

NA

MUCK DATA		PCT(+)6 IN.SIZE	PCT(+)6 IN.SIZE	PER CENT HY WEIGHT BETWEEN SCREENS		N016	N030	N050	N0100	N0200	PCT (-) ND200
DRY WT	MOISTURE PCF	WT PCT	PCF	6IN.	3IN.	1IN.	1/2IN.	N04	N08	N016	
108	9.0	0.0		0.0	0.0	7.6	17.0	13.4	4.5	4.9	8.4
										10.2	7.7
											20.9

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUND E=IRREGULAR P=PLATY C=CUBIC I=ELONGATED SP=SPHEROID

POT VOL CHANGE (-)0.056 IN.SIZE	LIQUID LIMIT PCT	PLASTIC LIMIT PCT	ATTERRBERG LIMITS SKINNAGE LIMIT PCT	SIZE(-)0.056IN. PLASTIC INDEX PCT	FLOW INDEX PCT	TOUGHNESS INDEX
PE	PE	PI	PI	PI	PI	PI
0	24.0	23.3	22.7	0.7	4.0	0.17

POF VOL CHANGE (-)0.056 IN.SIZE	LIQUID LIMIT PCT	PLASTIC LIMIT PCT	ATTERRBERG LIMITS SKINNAGE LIMIT PCT	SIZE(-)0.056IN. PLASTIC INDEX PCT	FLOW INDEX PCT	TOUGHNESS INDEX
PE	PE	PI	PI	PI	PI	PI
0	24.0	23.3	22.7	0.7	4.0	0.17

(-)10.75 IN.SIZE SPFCIF GRAVITY	ANGLE/REPULSE 1 IN.DROP DEGREES AT 9.8 PCT MOIST	MATERIAL ANGLE/SIDE 10'N DROP DEGREES AT 9.8 PCT MOIST	SIZE(-)12.0 ANGLE/REPULSE 10'N DROP DEGREES AT 9.8 PCT MOIST	APPARENT COHESION PSF AT 9.3 PCT MOIST	BULK DENSITY PCF AT 9.3 PCT MOIST	ANGLE INTER FRICTION DEGREES AT 9.3 PCT MOIST
2.57	39	37	40	125	75	30

QL-I CURRENT: 1 SEPT. 1972

KEY

24A
TUNNEL DATA

TUNNEL	VENTILATION	WATER INFLOW	UTILITY LINES	POWER SYSTEM
SIZE 11FT.	GRADE +1-3PCT	CF4 PRESS EXHST 4K	SIZE 14IN X	PRIMARY 4160V SECONDARY 480V
HAULAGE SYSTEM				
MUCK RAIL	PERSONNEL RAIL	SUPPLY RAIL	HOLD TYPE SIZE ROOF PLATE	SET SIZE SHAPE OCCASIONAL SEMI- CIRCULAR PLATES PIVOTED AT SPRING LINE AT FAULTS

MACHINE EXCAVATION

MACHINE	CUTTERS, MAKE, TYPE & DIAM. CUTTING EDGES		RPM	TORQUE MAX/OPERATE	
MAKE JARVA	MODEL MARK 11-1100	WT TONS	CENTER 2 REED STEEL TRIPLE DISC	HEAD 10.75 INTEG KFTLB KFTLB 244	CENTER KFTLB KFTLB 377
ANCHOR PRESS KLB 3402	MUCK SYSTEM BUCKET FROM FACE, CONVEYOR BELT TO REAR	POWER SYSTEM 4-125HP ELECT. MOTORS, 40HP MOTORS, HYDRAULIC	GUIDANCE LASER KLB 3.53	THRUST/SQ FT KLB 3.53	

CONVENTIONAL EXCAVATION

MACHINE JUMBO MACHINES	ROUND, NO. HOLES DEPTH DIAM. CUT.	BLASTING	MUCKING	GUIDANCE
FEEO LENGTH	EXPLOSIVES, POWER FACTOR TOTAL LBS PRIMERS, TRIM INTERIOR CUT LEFFTERS			

KEY	IDENTIFICATION	ROCK PROPERTIES	DRY WT	COMPR STRNTH	RIGID PCT	SHORE PCF	HARDNESS
25	MB SEDIMENTARY - GRAYWACKE (ARGILLACEOUS QUARTZITE) MASSIVE TO MEDIUM BEDDED, HIGHLY FOLDED AN. FRACTURED NO-VAL OIL IF 30 DEGREES TO 45 DEGREES	SAMPLE NO MB-2	KP51	PCF	MOH	SCMH10	•••••

WICK DRY AT PCF MOISTURE PCT IN. SIZE 6IN. 3IN. 2IN. 1 1/2IN. NO4 NO8 NO16 NO30 NO50 NO100 NO200 NO200

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

POT VOL CHANGE (-)	IN-SIZE	SP.C.F.C GRAVITY	IN.SIZE	MATERIAL	SIZE (-)	IN.	APPARENT ANGLE/EPOSE I IN DROP DEGREES AT OEGRRES AT PCT MOIST	BULK DENSITY PSF AT PCT MOIST	SIZE (-) ANGLE INTER FRICTION DEGREES AT PCT MOIST
LIMITS	PCT	LIMITS	PCT	LIQUID LIMIT	PLASTIC LIMIT	SKINNAGE LIMIT	ATTERBERG LIMITS	INCHES	IN.
							SIZE (-)		
							ANGLE		
							INTER		
							FRICTION		
							DEGREES		
							AT		
							PCT		
							PCT		

M8-2
CURRENT: 1 SEPT. 1972

xv

254 TUNNEL DATA

131

POWER SYSTEM					
TUNNEL	VENTILATION	WATER INFLOW	UTILITY LINES	PRIMARY	SECONDARY
SIZE 10 FT RECT 10.8 FT	GRADE •2.0 PCT	CFM BK	PRESS EXHST X	SIZE 16 IN	HP 30
				GPM NONE	AIR WATER PUMP 6 IN 4 IN
HAULAGE SYSTEM	SUPPORT SYSTEM	SUPPLY RAIL	BOLT TYPE SIZE 6 FT X .75 IN	ROOF PLATE AS REQUIRED	SHOTCRETE
MUCK RAIL 140-200CF BOTTOM DUMPCARS	PERSONNEL RAIL				
60-80LB RAIL 10T MOTOR 30 IN GAGE					

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CONVENTIONAL EXCAVATION

MACHINE	ROUND.	EXPLOSIVES*	BLASTING	MUCKING
JUMBO 2 BOOM	NO. HOLES 36	POWDER FACTOR 7.5LB/CY	IGNITER CORD	EIMCO
MACHINES D-93	DEPTH 8 FT	TOTAL LBS 210	FUSE + CAPS	40
RUINO	DIAM. 1 5/8IN	PRIMERS 10LB.	DETARIME	
	CUT. V	TRIM ANFO		
FEEED LENGTH 10FT		INTERIOR ANFO		
		CUT ANFO		
		LIFTER ANFO		

KEY	IDENTIFICATION	ROCK PROPERTIES	ORIGIN	COMPR. STRNTH K ^W SI	ROD PCT	SHORE MOH	HARNESS SCHMIOT
26	S-1	SEISMIC: SANDSTONE FINE GRAINED. WELL COMPACTED, LIGHT BROWN OVER 50 PCT QUARTZ.	ORY WT PCF				
	SAMPLE NO S-1			166	22	92	61 NA NA

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES **A=ANGULAR** **S=SQUARE** **R=ROUND** **P=PLATE** **C=CUBIC** **I=REGULAR** **E=ELONGATED** **SP=SPHEROID**

卷之三

POT VOL CHANGE 1-10.065 IN.SIZE		MATERIAL SIZE(-)12.0 ANGLE/REPPOSE 1 IN DROP DEGREES AT 6.3 PCT MOIST		SIZE(-)12.0 TOUGHNESS INDEX	
PCT	LIQUID LIMIT PCT	PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX
0	16.90	15.50	15.18	1.40	5.0
					0.28
(-)10.75 IN.SIZE SPECIFY GRAVITY		MATERIAL SIZE(-)12.0 ANGLE/SLIDE 10 IN DROP DEGREES AT 6.3 PCT MOIST		SIZE(-)12.0 ANGLE INTER FRICTION DEGREES AT 4.8 PCT MOIST	
BULK DENSITY PCF AT PCT MOIST	APPARENT COHESION PSF AT PCT MOIST	BULK DENSITY PCF AT PCT MOIST	APPARENT COHESION PSF AT PCT MOIST	BULK DENSITY PCF AT PCT MOIST	APPARENT COHESION PSF AT PCT MOIST
28	29	NA	NA	NA	29
2.73	35				29

CURRENT: 1 SEPT. 1972

KEY

26A
TUNNEL DATA

TUNNEL	VENTILATION	WATER INFLOW	UTILITY LINES	POWER SYSTEM		
SIZE	GRADE	CFM	PRESS EXHST	HP	PRIMARY	SECONDARY
18 FT 1 IN	-7.0 PCT	17K	X	36IN 7S	GPM S-10	2IN 4IN
HAULAGE SYSTEM				SUPPORT SYSTEM		
MUCK 30IN PIGGYBACK CONVEYORS. 36IN SUSPENDED CONVEYOR	PERSONNEL DIESEL TRUCKS, JEEPS	SUPPLY DIESEL TRUCKS, JEEPS	BOLT TYPE SIZE 4-S/8IN X 4FT	ROOF PLATE 8.2LB CHANNEL. 6IN X 9.5FT ON 13.5FT AT 4FT OR 2FT	SET SIZE SHAPE	SHOTCRETE

MACHINE EXCAVATION

MACHINE	CUTTERS, MAKE, TYPE, DIAM, CUTTING EDGES	RPM	TORQUE + MAX/OPERATE	THRUST + MAX/OPERATE	
MAKE	MODEL	WT	HEAD CENTER	HEAD CENTER	
ROBBINS	18I-122	WT 260 TONS	CENTER 1 ROBBINS. 7.5IN TRIPLE STEEL DISC	4.5 INTEG	KFTL811720 KFTL8
			INTERIOR 4.3 ROBBINS. 12IN STEEL DISC		KFTL8 KFTL8
ANCHOR PRESS	MUCK SYSTEM BUCKETS FROM FACE. 30IN CONVEYOR TO REAR	POWER SYSTEM 6-270HP MOTORS FOR HEAD	GUIDANCE LASER	THRUST/SQ FT KLB 3.56	KLB 1580 KLB 914

CONVENTIONAL EXCAVATION

MACHINE	BLASTING	MUCKING	GUIDANCE
JUMBO	NO. HOLES	DEPTH	PRIMERS.
MACHINES		DIAM.	TRIM
FEED LENGTH	CUT.	INTERIOR	CUT
		LIFTERS	

KEY IDENTIFICATION
27 7-2
ROCK PROPERTIES
SEDIMENTARY: SANDSTONE FINE
GRAINED, WELL COMPACTED,
LIGHT BROWN, OVER 50 PCT
QUARTZ.
SAMPLE NO
7-2

MUCK DATA
DRY UNIT MOISTURE PCT (+) 16 * * * * * PER CENT BY WEIGHT BETWEEN SCREENS
WT PCF IN. SIZE 6IN. 3IN. 2IN. 1IN. 1/2IN. NO^a ND16 ND30 ND50 ND100 ND200 *
PCT (+)
NO200

	PI	PI	PI	PI	PI	PI	PI	A	A					
90	4.0	0.0	1.5	0.9	33.1	22.6	15.4	4.3	2.6	1.4	1.2	2.5	3.8	10.7

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUND P=PLATEY C=CUBIC I=IRREGULAR ELONGATED SP=SPHEROID

POT VOL CHANGE
(-) 0.056 IN. SIZE
LIQUID LIMIT
PICT
0
PI PI PI PI PI PI PI PI A A A A

ATERRING LIMITS..0 SIZE (-) 0.056 IN.
SHRINKAGE PLASTICITY
LIMIT INDEX
PICT
23.0 17.63 17.58 5.37 6.90 0.78

TOUGHNESS
INDEX

ANGLE/REPULSE
SPECIFIC GRAVITY
(-) 0.75 IN. SIZE
ANGLE/REPULSE
1 IN. DROP
DEGREES AT
2.6 PCT MOIST
MATERIAL SIZE (-) 12.0 IN.
ANGLE/SLIDE
10 IN. UP
DEGREES AT
2.6 PCT MOIST
ANGLE INTER
STEEL PLATE
DEGREES AT
2.6 PCT MOIST
BULK DENSITY
PSF AT
2.6 PCT MOIST
FRICTION AT
DEGREES AT
2.6 PCT MOIST
2.6 PCT MOIST
SIZE (-) 12.0 IN.

2.63 32 31 29 0 92.8 64

7-2 CURRENT: 1 SEPT. 1972

KEY

27A TUNNEL DATA

TUNNEL				VENTILATION			WATER INFLOW			UTILITY LINES			POWER SYSTEM	
SIZE 16FT 11IN	SHAPE ROUND	GRADE +2.0PCT	CFM 17K	PRESS EXHST X	SIZE 36IN	HP 75	GPM 5-10	AIR 2IN	WATER 2IN	PUMP 4IN	PRIMARY 4160V	SECONDARY 480V		
HAULAGE SYSTEM														
MUCK 30IN PIGGYBACK CONVEYOR	PERSONNEL DIESEL TRUCKS	SUPPLY DIESEL TRUCKS, JEEPS	DOLT TYPE 4-5/BIN X 4FT	ROOF PLATE 6" X 21.8 CHANNEL 6IN X 9.5FT OR 13.5FT AT 4FT OR 2FT	SET SIZE SHAPE						SHOTCRETE			

MACHINE EXCAVATION

MACHINE	CUTTERS, MAKE, TYPE, U.I.A.N., CUTTING EDGES	RPM	TOQUE, MAX/OPERATE	THRUST, MAX/OPERATE
ROBBINS 16I-122	CENTER 1 ROBBINS 7.5IN TRIPLE STEEL DISC	HEAD CENTER 4.5 INTEG	KFTLB KFTLB	KFTLB KFTLB
WT 260 TONS	INTERIOR 41 ROBBINS 12IN STEEL DISC	HEAD 4.5 INTEG	KFTLB KFTLB	KFTLB KFTLB
	GAGE ROBBINS 12 STEEL DISC			
KLB				
ANCHOR PRESS	MUCK SYSTEM BUCKETS FROM FACE. 30IN CONVEYOR TO REAR	POWER SYSTEM 4-200HP MOTORS FOR HEAD	GUIDANCE LASER	THRUST/SQ FT KLB 2.91

CONVENTIONAL EXCAVATION

MACHINE JUMBO MACHINES	ROUND, NO. HOLES DEPTH DIAM. CUT.	BLASTING	HUCKING	GUIDANCE
FEED LENGTH	EXPLOSIVES, POWDER FACTOR TOTAL LBS PRIMERS, TRIM INTERIOR CUT LIFTERS			

KEY IDENTIFICATION
28. II-3

ROCK PROPERTIES
SEDIMENTARY: SHALE. MASSIVE TO
 THINLY LAMINATED. INTERBEDDED
 SILTSTONE AND SHALE. WITH
 MINOR SANDSTONE AND LIMESTONE
 LAYERS. GRAIN SIZE FINE TO
 COARSE. QUARTZ 24 TO 33 PCT.

MUCK DATA	DRY UNIT	MOISTURE	PCT (+) 16 IN. SIZE	PCT (-) PCF	PER CENT BY WEIGHT	BETWEEN SCREENS	N04	N08	N016	N030	N050	N0100	N0200	PCT (-) N0200
99	1.1	7.8	12.6	11.3	14.4	14.9	16.4	5.7	3.5	2.0	1.4	1.1	0.9	8.0

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES **A=ANGULAR** **S=SQUARE** **R=ROUND** **P=PLATY** **C=CUBIC** **I=IRREGULAR** **AP=E-ELONGATED** **CR=COMPRESSED**

A A A A A A A A A A

POT VOL CHANGE (-10.056 IN.SIZE	LIQUID LIMIT PCT	PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	SIZE (-) 0.056 IN.	PLASTICITY INDEX PCT	FLOW INDEX PCT	TOUGHNESS INDEX
0	15.60	14.81	14.51	0.79	3.00	0.26	

(-)0.75 IN. SIZE		MATERIAL SIZE : -12.0 IN.		SIZE : -12.0 IN.	
SPFCIF	ANGLE/REPOSE	ANGLE/SLIDE	APPARENT	BULK	ANGLE INTER
GRAVITY	1 IN. OROP	10 IN UROP	STEEL PLATE	CHEMOSION	FRICITION
	OEGRREES AT	OEGRREES AT	OEGRREES AT	PCF AT	DEGREES AT
	1.0 PCT MOIST	1.0 PCT MOIST	1.0 PCT MOIST	0.2 PCT MOIST	0.2 PCT MOIST

2.65 25 25 29 550 100 94

KEY

28A
TUNNEL DATA

TUNNEL	SHAPE	VENTILATION	WATER INFLOW	UTILITY LINES	POWER SYSTEM
SIZE	CFM	PRESS. EXHST	GPM	AIR	PRIMARY
24' X 7' + 5' T.S.P.T.	All-look X	None	4IN	4IN	SECONDARY 110V
HAULAGE SYSTEM		SUPPORT SYSTEM			
MOTOR VASCHE: ST-5 SCOOTER TRAIL, LOTUS SHUTTLE CARS	PERSONNEL DIESEL TRUCKS, JEEPS	SUPPLY DIESEL TRUCKS, JEEPS	BOLT-TYPE 5/8IN X 6FT 4FT X 4FT PATTERN	HOOF PLATE 11IN X 10FT	SET SIZE-SHAPE
					SHOTCRETE

CONVENTIONAL EXCAVATION

MACHINE	CUTTERS, MAKE, TYPE, DIA.M., CUTTING EDGES	RPM	TORQUE, MAX/OPERATE	THRUST, MAX/OPERATE
MAKE	MODEL	WT	HEAD	HEAD
	CENTER		KFTLB	KFTLB
	INTERIOR		KFTLB	KFTLB
	GAGE		KLB	KLB
ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
				KLB

CONVENTIONAL EXCAVATION

MACHINE	ROUNDS,	EXPLOSIVES,	MUCKING	GUIDANCE
JUMBO 2' 800H HYDROJIB	NO. HOLES 35	POWDER FACTOR 3.5LB/CY	SCOOPTRAM	TRANSIT
MACHINES 2-AR93	DEPTH 10.5FT - 11FT	TOTAL LBS 234	LASER	
DRIFTERS	DIA.M. 1-3/4IN	PRIMERS, 16LB		
	CUT, V	1.25IN X 8IN, 75PCT		
FEED LENGTH 14FT	1-6FT BUSTER	TRIM 11LB 1.25IN X 12IN, COALITE SY		
	HOLE	INTERIOR AWFO		
	SF./HOLE 5.1	CUT		
	LIFTERS 32LB 1.25IN X 12IN, RXL 60PCT	LIFTERS		

KEY IDENTIFICATION
29 11-4

ROCK PROPERTIES
 SEDIMENTARY: SHALE, MASSIVE TO
 THINLY LAMINATED, INTERBEDDED
 SILSTONE AND SHALE WITH MINOR
 SANDSTONE AND LIMESTONE LAYERS
 GRAIN SIZE FINE TO COARSE,
 QUARTZ 24 TO 33 PCT.

SAMPLE NO.
11-4

					DRY WT	CDMPR STRAH KPSI	ROD PCT EST	SHORE MOH	SCHMIDT
					PCF				
					166	4 MAJOR BEDS 22 TD 29. 3 HIND BEDS 12 TD 17. WT. AVE 22.	90	PARALLEL 41SS. NORMAL 41-54.	NA NA

MUCK DATA DRY UNIT WT PCF	MOISTURE PCT	PCT(+) IN.SIZE	PER CENT BY WEIGHT BETWEEN SCREENS						PCT (-) ND200
			HD8	ND16	ND30	NO50	ND100	NO200	
96	1.1	8.2	17.7	17.0	19.3	15.7	12.7	3.4	1.3

SHAPE OF FRACTION BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SUPERIOR

PA PA PA PA PA PA A A A

PDT VOL CHANGE (-)0.056 IN.SIZE	LIQUID LIMITS PCT	AT TERBERG LIMITS			SIZE(-) 0.056 IN.	PLASTICITY INDEX PCT	FLOW INDEX PCT	TOUGHNESS INDEX PCT
		PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	SIZE(-) 0.056 IN.				
0.	15.80	15.60	13.26	0.20	4.00	4.00	0.05	0.05

(-)0.75 IN.SIZE SPECIFIC GRAVITY	ANGLE/REPOSE 1 K DROP DEGREES AT 0.9 PCT MOIST	MATERIAL SIZE(-)2.0 IN.			ANGLE/SIDE STEEL PLATE DEGREES AT 0.9 PCT MOIST	APPARENT COHESION PSF AT 0.2 PCT MOIST	BULK DENSITY PCF AT 0.2 PCT MOIST	SIZE(-)2.0 IN. ANGLE INTER FRICITION DEGREES AT 0.2 PCT MOIST
		ANGLE/REPOSE 10 IN DROP DEGREES AT 0.9 PCT MOIST	STEEL PLATE DEGREES AT 0.9 PCT MOIST	PSF AT 0.2 PCT MOIST				
2.79	2.8	2.8	2.82	100	54			

KEY

29A
TUNNEL DATA

TUNNEL						VENTILATION			WATER INFLOW			UTILITY LINES		
SIZE 18FTx8 .SFT	SHAPE RECT	GRADE 0.0	CFM 20K	PRESS ENTRY FACE	EXHST	SIZE 40	HP NONE	GPM	AIR 2IN	WATER NONE	PUNK?	PRIMARY 4160V	SECONDARY 600V	
MUCK OISEL SHUTTLE CAR CONVEYOR	PERSONNEL OISEL TRUCK	SUPPLY DIESEL TRUCK	BOLT TYPE 5/8IN X 6FT AT 4FT X 4FT	SUPPORT SYSTEM	ROOF PLATE	SET SIZE SHAPE	SHOTCRETE							

MACHINE EXCAVATION

MACHINE			CUTTERE, MAKE, TYPE, U.I.A.M., CUTTING EGGS			RPM			TORQUE, MAX/OPERATE			THRUST, MAX/OPERATE		
MAKE	MODEL	WT	CENTER	INTERIOR	GAGE	HEAD CENTER	HEAD	HEAD	CENTER	HEAD	KFTLB	KFTLB	KLB	
ATLAS - COPCO	4-HEAD	180 L.T.	48 T.C.	ORAG HEADS	ON 4 ROTATING	3 1/4UPPER 1 S-BLOWER	KFTLB KFTLB	KFTLB KFTLB	KFTLB	KFTLB	KFTLB	KFTLB	KLB 1,093 KLB	

ANCHOR PRESS KLB 1000	MUCK SYSTEM FLIGHT CONVEYOR STAR WHEEL, 25IN CONVEYOR	POWER SYSTEM 4-60KW MOTORS HEAD MOTION 2-78KW MOTORS	GUIDANCE TRANSIT LASER	THRUST/SQ FT KLB

CONVENTIONAL EXCAVATION

MACHINE			EXPLOSIVES, POWDER FACTOR TOTAL LBS PRIMERS, TRIM INTERIOR CUT LIFTERS						BLASTING			MUCKING		
JUMBO MACHINES	NO. HOLES	DEPTH	DIAM.	CUT,	FEED LENGTH									

KEY IDENTIFICATION
30 72-1
SAMPLE NO
72-1

ROCK PROPERTIES
SEDIMENTARY: SHALE
INTERBEDDED SILTSTONE
• SHALE MINOR SANDSTONE
♦ LIMESTONE. FINE TO
COURSE GRAINED

	WET DATA	DRY UNIT WT	MOISTURE PCT	IN. SIZE	PCT(%)	PER CENT BY WEIGHT BETWEEN SCREENS	DRY WT PCF	COMPR STRNTH KPSI	ROD PCT EST	HARDNESS SHORE MOH SCHMIDT	PCT (-) ND200
86	1.5	0.0	0.0	5IN. 2IN. 1IN.	18.6 24.23	31.0 20.7.3	26.1 4.5	1.1 1.5	1.2 0.6	5.9	

SCREEN ANALYSIS: UPPER LINE, DRY SCREENED (ASTM C13c). AFTER WASHING (ASTM C117). LOWER LINE, SCREENED BEFORE DRYING

SHAPE OF FRACTIONN BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

P-E P P P P P-A P-A A

	Liquid LIMIT	Plastic Limit	Shrinkage Limit	Plasticity Index	Flow Index	Toughness Index
0	18.00	17.10	15.58	0.90	4.40	0.20

POF VOL CHANGE (-10.0SS IN. SIZE	LIQUID LIMIT	PLASTIC LIMIT	SHRINKAGE LIMIT	PLASTICITY INDEX	FLOW INDEX	TOUGHNESS INDEX	SIZE (-12.0 IN.)	ANGLE INTER. FRICITION	BULK DENSITY	CHEMOSION	PSF AT 1.0 DEGREES AT 1.0 PCT MOIST	DEGREES AT 1.0 PCT MOIST
2.72	36	32	30	41	170	100						

72-1 CURRENT: 1 SEPT. 1972

KEY

30A
TUNNEL DATA

VENTILATION				WATER INFLOW			UTILITY LINES		POWER SYSTEM		
TUNNEL	SHAPE	GRADE	CFM	PRESS	EXHST	SIZE	HP	GPM	AIR	WATER	PUMP
SIZE 18 FT 1 IN	ROUND	+10.0PCT	18K	X	J6	1N	12G	5-10	2 IN	4IN	4160 480

SUPPORT SYSTEM				SET SIZE SHAPE			SHOTCRETE		GUIDANCE	
MUCK	PERSONNEL	SUPPLY	DIESEL	DOT	TYPE	SIZE	ROOF PLATE			
30 IN PIGGYBACK	TRUCKS	FURKS	6-6FTx5/8 IN	6-6FTx5/8 IN	8.2 LB CHANNEL	8.2 LB CHANNEL				
CONVEYOR 36 IN		JEEPS	6 IN X 9.5FT OR		6 IN X 9.5FT OR					
SUSPENDED			13.5 FT AT 2 FT		13.5 FT AT 2 FT					
CONVEYOR										

MACHINE EXCAVATION

CUTTERS, MAKE, TYPE, DIAM., CUTTING EDGES				RPM			TORQUE, MAX/OPERATE		THRUST, MAX/OPERATE	
MACHINE	GRADE	CENTER	INTERIOR	GAGE	HEAD, CENTER	HEAD	CENTER	HEAD	HEAD	HEAD
MAKE ROBBINS	MODEL 181-122	WT 260	1RD, 1NS OISC 7.SIN TRIPLE W/	4.5 ROBBINS OISC 12IN. ESCO RING	3 ROBBINS OISC 12IN. ESCO RING	4.5	KFTLB	KFTLB	KFTLB	KFTLB

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST / SQ FT
KLB 1000	BUCKETS TO BELT	4-200 HP FOR HEAD	LASER	KLB

CONVENTIONAL EXCAVATION

MACHINE	ROUND, NO. "HOLES	BLASTING	HUCKING	GUIDANCE
JUMBO MACHINES	DEPTH DIAM. CUT.			
FEED LENGTH	CUT LIFTERS			

KEY IDENTIFICATION
31 MSU
SAMPLE
MSU-1

ROCK PROPERTIES
SEDIMENTARY: CONGLOMERATE
(ARFCCIA) 25 IN TO 10 IN
ROUNDED TO ANGULAR BOULDERS
COBBLES, PEBBLES.
PREDOMINATELY LIMESTONE
MATPIX, W/CHERT, SCHIST,
DIRASE FRAGMENTS

MUCK DATA	DRY UNIT WT	MOISTURE PCT	PCT(+)16 IN SIZE	PER CENT BY WEIGHT BETWEEN SCREENS	NO16	NO30	NO50	NO100	NO200	PCT (-)
	#T PCF	PCT	6IN. 2IN. 1IN.	1/2IN.	NO4	NO8	NO16	NO30	NO50	NO200
104	5.6	0	17.0 12.0 24.0	18.0	16.0	6.0	3.0	2.0	1.0	0.0

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUND E=CUBIC I=IRREGULAR P=ELONGATED SP=SPHEROID

POT VOL CHANGE (-10.056 IN SIZE)	LIQUID LIMIT PCT	PLASTIC LIMIT PCT	ATTENBERG SHILOH SIZE(-)12.0 IN	SHILOH SIZE(-)12.0 IN	PLASTICITY INDEX PCI	FLOW INDEX FCI	TOUGHNESS INDEX TCI	SIZE(-)12.0 IN.
0	13.80	12.77	16.78	16.78	1.03	3.20	0.32	

(-)10.75 IN SIZE	SPECIF GRAVITY	ANGLE/REPOSE IN C-LOP DEGREES AT 0.4 PCT MOIST	ANGLE/REPOSE IN C-LOP DEGREES AT 0.4 PCT MOIST	MATERIAL SIZE(-)12.0 IN	ANGLE/SLIDE STEEL PLATE DEGREES AT 0.4 PCT MOIST	APPARENT COHESION PSF AT 0.3 PCT MOIST	BULK DENSITY PCF AT 0.3 PCT MOIST	SIZE(-)12.0 IN. ANGLE INTER FRICTION DEGREES AT 0.3 PCT MOIST
2.74	3.5	29	27	410	111	46		

MSU-1 CURRENT: 1-SEPT. 1972

KEY
3IA
TUNNEL DATA

TUNNEL	SIZE	SHAPE	GRADE	CFM	PRESS EXHST	SIZE	HP	GP/H	WATER INFLOW	UTILITY LINES	POWER SYSTEM
9 FT 10 FT	RECT		0.0	10K	X	24 IN	50	NONE	AIR 6 IN 2 IN.	WATER PUMP	PRIMARY 4168 SECONDARY 480
HAULAGE SYSTEM											
MUCK RAIL	PERSONNEL RAIL		SUPPLY RAIL	BOLT, TYPE	SIZE	ROOF PLATE					
44CF ROCKERCARS				2 FT X 5/8 IN	3FT-.6FT-.6FT						
4-6T MOTORS				21 BOLTS/5 FT	6 PLATES/SFT						
30 LB RAIL				SPAN	FT						
18 IN GAGE											

CONVENTIONAL EXCAVATION

MACHINE	MAKE	MODEL	WT	CENTER	INTERIOR	GAGE	RPM	TOQUE, MAX/OPERATE	THRUST, MAX/OPERATE
							KFTLB KFTLB	KFTLB KFTLB	KLB KLB

CONVENTIONAL EXCAVATION

MACHINE SUM=3 300M MACHINES 3IN DIA ORIFTER FEED LENGTH 7FT	ROUND, NO. MOLES 42-50 DEPTH 5.5 FT DIAM. 1 3/8 IN CUT, V	EXPLOSIVES, POWER FACTOR 8.2 LB/CY TOTAL LBS 150 PRIMERS, 25 LB AMOGEL NO. 4 TRIM CARBONITE INTERIOR CARBONITE CUT CARBONITE LIFTERS CARBONITE	BLASTING ELECTRICAL IGNITER CORD NO. 6 CAPS, FUSE	HUCKING EIMCO 21	GUIDANCE LASER
---	---	---	--	------------------------	-------------------

KEY
32
MSU
SAMPLE NO
MSU-2

ROCK PROPERTIES
SEDIMENTARY: CUNGLOMERATE
1/4 - 10 IN ROUNDS TO ANGULAR
ROULERS, COBBLES, PEBBLES
IN PREDOMINATELY LIMESTONE
MATRIX. W/CHERT, SCHIST
DIARASE FRAGMENTS WELL
TO MODERATELY CONSOLIDATED

	DRY WT PCF	COMPR STRNTH KPSI	ROD PCT	SHORE MOH	HARDNESS SCHMIDT
		80			

MUCK DATA	PER CENT MY WEIGHT BETWEEN SCREENS	PCT (-)
DRY UNIT WT PCF	PCT(+)16 IN.SIZE IN.	6IN. 3IN. 2IN. 1IN. 1/2IN. NC ₄
		N030 N050 N0100 F0200

POT VOL CHANGE (-)	LIQUID LIMIT PCT	PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX PCT	TOUGHNESS INDEX PCT	SIZE (-) IN.
107	19.1	28.9	17.2	16.0	10.4	5.1	1.5
							0.7

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLAY C=CUBIC I=IRREGULAR E=ELONGATED SP=Spheroid

A A A A A A A A

(-) IN.SIZE	MATERIAL SIZE (-)	ANGLE/REPOSE 1 IN DROP DEGREES AT PCT MOIST	ANGLE/REPOSE 10 IN DROP DEGREES AT PCT MOIST	ANGLE/SLIDE STEEL PLATE DEGREES AT PCT MOIST	APPARENT COHESION PSF AT PCT MOIST	BULK DENSITY PCF AT PCT MOIST	SIZE (-) IN. ANGLE INTER FRICTION DEGREES AT PCT MOIST

KEY

32A
TUNNEL DATA

TUNNEL				VENTILATION			WATER INFLOW			UTILITY LINES			POWER SYSTEM	
SIZE 9FT 0 FT	SHAPE RECT	GRADE 0.0	CFM 9K	PRESS X	EXHST 24 IN	SIZE 50	HP NONE	GPM 6 IN 2 IN	AIR WATER PUMP	PRIMARY 4160	SECONDARY 480			
HAULAGE SYSTEM														
MUCK RAIL 44CF WOCKER DUMP 30LB RAIL 18 IN GAGE	PERSONNEL RAIL		SUPPLY RAIL		SUPPORT SYSTEM	BOLT TYPE SIZE 6 FT X 5/8 IN 21 BOLTS/5 FT SPAN	ROOF PLATE 3x4 1/2, 6 FT 7 PLATES 1 SPAN	SET SIZE SHAPE		SHOTCRETE				

MACHINE EXCAVATION

MACHINE				CUTTERS, MAKE, TYPE, U.I.A.W., CUTTING EDGES			RPM			TORQUE, MAX/OPERATE			THRUST, MAX/OPERATE	
MAKE	MODEL	WT	CENTER	INTERIOR	INTERIOR	GAGE	HEAD	CENTER	HEAD	KFTLB	KFTLB	KFTLB	KLB	KLB
ANCHOR PRESS	MUCK SYSTEM		POWER SYSTEM		GUIDANCE	THRUST/SQ FT								
KLB					KLB									

CONVENTIONAL EXCAVATION

EXPLOSIVES, ROUND, NO. HOLES 50 DEPTH 5.5 FT DIAM. 1 3/8 IN CUT, V	POWDER FACTOR 6.7 TOTAL LBS 122 PRIMERS, ANGEL TRIM INTERIOR ANGEL OR CARBONITE	BLASTING ELECTRICAL IGNITER CORD 21 FUSE ND. 6 CAPS	HUCKING EIMCD IGNITER CORD 21 FUSE ND. 6 CAPS	GUIDANCE LASER
MACHINE JUMPER 2 900M MACHINES 3IN DIA DRIFTER	FEED LENGTH 6FT	CUT LIFTERS		

KEY IDENTIFICATION
33 LAWRENCE
SAMPLE NO
LAW-2

ROCK PROPERTIES
SEDIMENTARY: LIMESTONE LIGHT
TO MEDIUM GRAY FINE GRAINED,
SOME CHERT NODULES, TRACES TO
OCCASIONAL CLAY PARTINGS

MUCK DATA	DRY UNIT WT	MOISTURE PCT	PCT IN SIZE	PER CENT BY WEIGHT BETWEEN SCREENS	ND6	ND16	ND30	ND50	ND100	ND200	PCT (-) ND200
92	7.2	0.0	0.0	3.0	25.0	18.0	22.1	9.4	6.5	3.5	2.0

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SQUARE ANGULAR R=ROUND P=PLATE C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROIDIC

PAI PI P_r PI I I AI A I

POT VOL CHANGE (-10.065 IN SIZE)	Liquid LIMIT PCT	PLASTIC SHANKAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX	TOUGHNESS INDEX
0	12.5	12.3	9.6	0.2	4.0

(-10.75 IN SIZE)	SPECIFIC GRAVITY	MATERIAL SIZE (-12.0 IN.)	ANGLE/REPPOSE 1 IN DROP DEGREES AT 5.4 PCT MOIST	ANGLE/REPPOSE 10 IN DROP DEGREES AT 5.4 PCT MOIST	APPARENT COHESION STEEL PLATE DEGREES AT 5.4 PCT MOIST	BULK DENSITY PSF AT PCT MOIST	FRICITION COHESION PSF AT PCT MOIST	SIZE (-12.0 IN.)
2.83	35	38	31	NA	NA	30	?	?

CURRENT: I SEPT. 1972

LAW-2

KEY

33A
TUNNEL DATA

TUNNEL	VENTILATION	WATER INFLOW	UTILITY LINES	POWER SYSTEM					
SIZE 13FT. 8IN	GRADE +0.25PCT	CFM 21K	PRESS EXHST X	HP 28IN	6IN	2IN	6IN	PRIMARY 4160V	SECONDARY 480V
HAILAGE SYSTEM				SUPPORT SYSTEM					
MUCK RAIL	PERSONNEL RAIL	SUPPLY RAIL	BOLT-TYPE NONE	ROOF PLATE	SET-SIZE-SHAPE		SHOTCRETE		

MACHINE EXCAVATION

MACHINE	CUTTERS, MAKE, TYPE, DIAM, CUTTING EDGES	RPM	TORQUE, MAX/OPERATE	THRUST, MAX/OPERATE
MADE	WT	HEAD, CENTER	HEAD 0	CENTER
ALKIRK H-ROCK	400 TONS	9 30	KFTLB KFTLB206	KFTLB KFTLB 614
	1 LAWRENCE TCB 24IN TRICONE	11-LAWRENCE TCB 15IN DISC 11-TCB 15IN		

ANCHOR PRESS	MUCK SYSTEM BUCKETS FROM FACE, CONVEYOR TO, REAR	POWER SYSTEM ELECTRO-HYDRAULIC 600HP HEAD 150 CENTER	GUIDANCE LASER	THRUST/SQ FT
KLE				KLB 4.28

CONVENTIONAL EXCAVATION

MACHINE JUMBO MACHINES	ROUND, NO. HOLES DEPTH, DIAM., CUT.	BLASTING	HUCKING	GUIDANCE
FEED LENGTH			EXPLOSIVES, POWDER FACTOR TOTAL LBS PRIMERS, TRIM INTERIOR CUT LIFTERS	

KEY IDENTIFICATION
24 LAWRENCE
SAMPLE NO
LAW-3

ROCK PROPERTIES
SEDIMENTARY: LIMESTONE LIGHT
TO MEDIUM GRAY, FINE GRAINED,
SOME CHERT NODULES. TRACES TO
OCCASIONAL CLAY PARTINGS.

	DRY UNIT WT	MOISTURE PCT	PCT ⁽⁺⁾ 6 IN. SIZE	PCT ⁽⁺⁾ 1/2 IN. SIZE	PER CENT BY WEIGHT BETWEEN SCREENS	NO ₄	NO ₈	NO ₁₆	NO ₃₀	NO ₅₀	NO ₁₀₀	NO ₂₀₀	PCT ⁽⁺⁾ NO ₂₀₀
93	5.5	0.0	0.0	4.3	25.9	19.6	20.2	7.4	5.0	3.5	1.8	1.1	9.9

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDERO P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPhEROID

PAI PAI PI PAI I I I I I I

POL VOL CHANGE (-0.065 IN. SIZE	Liquid LIMIT PCT	Plastic LIMIT PCT	Atterberg Limits SIZE (-) 0.1 AS IN. SMINKEAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX PCT	TOUGHNESS INDEX
0.	11.6	10.6	10.0	1.2	2.9	0.41

(-0.75 IN. SIZE) ANGLE/REPPOSE GRAVITY	ANGLE/REPPOSE 1 IN. DROP DEGREES AT 6.1 PCT MOIST	MATERIAL SIZE (-) 2.0 ANGLE/SLIDE 10 IN. DROP DEGREES AT 6.1 PCT MOIST	IN..... STEEL PLATE DEGREES AT H.4 PCT MOIST	APPARENT COHESION PSF AT PCT MOIST	BULK DENSITY PCF AT PCT MOIST	SIZE (-) 2.0 ANGLE/INTER FRICTION DEGREES AT 7 PCT MOIST
2.80	41	40	36	NA	NA	32

LAW-3 CURRENT: 1 SEPT. 1972

KEY

34A
TUNNEL DATA

TUNNEL	VENTILATION	WATER INFLOW	UTILITY LINES	POWER SYSTEM					
SIZE 13FT 8IN	GRADE +0.25PCT	CFM 20K	PRESS EXHST X	HP 40-120	AIR 6IN 2IN	WATER 6IN	PUMP 6IN	PRIMARY 4160V 480V	SECONDARY
HAULAGE SYSTEM			SUPPORT SYSTEM	HOLD, TYPE NONE	SIZE	ROOF PLATE	SET, SIZE, SHAPE	SHOTCRETE	
MUCK RAIL	PERSONNEL RAIL	SUPPLY RAIL							

MACHINE EXCAVATION

MACHINE	CUTTERS, MAKE, TYPE, DIAM.	CUTTING EDGES	RPM	THROTTLE, MAX/OPERATE	THRUST, MAX/OPERATE				
ALKIRK	HARDROCK	WT 400 TONS	INTERIOR 11 LAWRENCE TCB 24IN TRICONIC	GAGE 11 LAWRENCE TCB 12IN OISC, 11 15IN ROLLER	HEAD, CENTER 9 30	KFTLB KFTLB	KFTLB KFTLB	KFTLB KFTLB	KFTLB KFTLB
			TCB 15IN ROLLER						

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THROTTLE/SQ FT
KLB	BUCKETS FROM FACE, 24IN CONVEYOR TO REAR	ELECTRO-HYDRAULIC 600HP MEAO 150 CENTER	LASER	KLB 4.228

CONVENTIONAL EXCAVATION

MACHINE	ROUND, NO. HOLES, DEPTH, DIAM., CUT,	BLASTING	MUCKING	GUIDANCE
JUMBO MACHINES				
FEED LENGTH				

KEY IDENTIFICATION
3S LAWRENCE
SAMPLE NO
LAW-4

POCK PROPERTIES
SEDIMENTARY: LIMESTONE LIGHT
TO MEDIUM GRAY FINE GRAINED.
SOME CHERT NODULES. TRACES TO
OCCASIONAL CLAY PARTINGS.

MUCK DATA	DRY UNIT WT	MOISTURE PCT	IN-SIZE PCF	PER CENT BY WEIGHT BETWEEN SCREENS	DRY WT PCF	COMPR STRNTH KPSI	ROD PCT EST	SHORE MOH	HARDNESS SCHMIDT	PCT (-) NO200
60	7.9	0.0	16	0.0 5.0 18.3 1d.3 17.0 7.3	160	19	100	46	NA	NA
80	7.9	0.0	16	0.0 5.0 18.3 1d.3 17.0 7.3	160	19	100	46	NA	NA

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUND ED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

P1 PI PI PI PI PA PA A

POT VOL CHANGE (-)-0.056 IN.SIZE	LIQUID LIMIT PCT	PLASTIC LIMIT PCT	AFTERBERG LIMITS SHRINKAGE LIMIT PCT	SIZE(-) 0.056 IN. PLASTICITY INDEX PCT	FLOU INDEX	TOUGHNESS INDEX	TOUGHNESS
0	20.2	20.0	13.5	0.2	4.7	0.05	
0	20.2	20.0	13.5	0.2	4.7	0.05	

(-)0.75 IN.SIZE SPECIF GRAVITY	ANGLE/REPOSE 1 IN DROP DEGREES AT 8.9 PCT MOIST	MATERIAL SIZE(-) 2.0 ANGLE/REPOSE 10 IN DROP DEGREES AT 8.9 PCT MOIST	ANGLE/SLIDE STEEL PLATE DEGREES AT 8.9 PCT MOIST	IN.....	APPARENT COHESION PSF AT PCT MOIST	BULK DENSITY PCF AT PCT MOIST	SIZE(-) 12.0 IN. ANGLE INTER FRICTION DEGREES AT 8.8 PCT MOIST
2.73	42	34	37	NA	NA	NA	28

LAW-4 CURRENT: 1 SEPT. 1972

KEY

35A

MACHINERY EXTRAVAGATI

CONVENTIONAL EXCAVATION

MACHINE JUMBO MACHINES	FEED LENGTH	MACHINING	HUCKING	GUIDANCE
ROUND. NO. HOLES	EXPLOSIVES.			
DEPTH	POWDER FACTOR			
	TOTAL LBS			
DIA.M.	PRIMERS,			
CUT.	TRIM			
	INTERIOR			
	CUT			
	LIFTERS			

KEY IDENTIFICATION
36 WILWAUKEE
SAMPLE NO
MIL-1

ROCK PROPERTIES
SEDIMENTARY: LIMESTONE. GRAY
FINE GRAINED. HORIZONTAL
JOINT SPACING 6 IN. TO 1 FOOT.

MUCK DATA DRY UNIT WT PCF	MOISTURE PCT	PCF (+) 6 IN. SIZE	PCF (-) 3IN. IN. SIZE	PER CENT BY WEIGHT BETWEEN SCREENS 6IN. 2IN. 1IN. 1/2IN. NO ₄	NO ₁₆	NO ₃₀	NO ₅₀	NO ₁₀₀	NO ₂₀₀	PCT (-) NO ₂₀₀		
89 5.5	0.0	0.0 0.0	14.5	28.0	24.0	8.2	6.2	4.8	4.2	2.0	0.5	7.6

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDERO P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

PE PI PI PA S S

POT VOL CHANGE
(-)0.056 IN.SIZE

Liquid LIMITS PCT	Plastic LIMIT PCT	Shrinkage Limit PCT	Plasticity Index PCT	Flow Index PCT	Toughness Index PCT
16.90	15.69	15.46	1.21	5.00	0.24

(-)10.75 IN.SIZE SPECIFIC GRAVITY	MATERIAL ANGLE/REPOSE 1 IN DROP DEGREES AT 2.5 PCT MOIST	SIZE(-)12.0 ANGLE/SIDE 10 IN DROP DEGREES AT 2.5 PCT MOIST	IN. STEEL PLATE DEGREES AT 2.5 PCT MOIST	APPARENT COHESION PSF AT 4.1 PCT MOIST	BULK DENSITY PCF AT 3.5 PCT MOIST	SIZE(-)12.0 ANGLE/INTER FRICITION DEGREES AT 3.5 PCT MOIST
2.89	36	35	30	95	86	35

MIL-1 CURRENT: 1 SEPT. 1972

KEY

36A
TUNNEL DATA

TUNNEL	VENTILATION	WATER INFLOW	UTILITY LINES	POWER SYSTEM							
SIZE 11FT 21IN	GRADE +0.2PCT	CFM 4K	PRESS EXHSF X	SIZE 1AIN	HP 25	GPM 5.	AIR 6IN	WATER 6IN	PUMP 6IN	PRIMARY 4680V	SECONDARY 440V
HAULAGE SYSTEM											
MUCK RAIL, 24IN GAGE STON MOTORS	PERSONNEL RAIL.	SUPPLY RAIL	SUPPORT SYSTEM	BOLT•TYPE SIZE	ROOF PLATE OCCASIONAL PINNED STEEL LAGGING	SET•SIZE•SHAPE 4IN H RING SETS IN FAULT ZONES	SHOTCRETE				

MACHINE EXCAVATION

MACHINE	CUTTERS•MAKE•TYPE•DIAM•CUTTING EDGES	RPM	TORQUE•MAX/OPERATE	THRUST•MAX/OPERATE
MAKE JARVA	CENTER 1 REED STEEL CONE, 5 DISC	HEAD, CENTER 9.3 INTEG	HEAD KFTLB KFTLB	CENTER KFTLB KFTLB
ANCHOR PRESS KLB 1650	BUCKET SYSTEM FROM FACE, 1AIN CONVEYOR TO REAR	POWER SYSTEM 6-50HP MOTORS FOR HEAD 1-40HP MOTOR HYDRAULIC	GUIDANCE LASER	THRUST/SQ FT KLB 6.09

CONVENTIONAL EXCAVATION

MACHINE	ROUND, NO. HOLES DEPTH DIAM. CUT.	BLAST:46	MUCKING	GUIDANCE
JUMBO MACHINES				
FEED LENGTH				

KEY IDENTIFICATION
37. MILWAUKEE
SAMPLE NO
MIL-2

ROCK PROPERTIES
SEDIMENTARY: LIMESTONE, GRAY,
FINE GRAINED, HORIZONTAL JOINT
SPACING 6 IN. TO 1 FOOT.

DRY WT
PCF

MOISTURE
PCT

IN.SIZE

6IN. 3IN. 2IN. 1/2IN.

PER CENT HY WEIGHT
BETWEEN SCREENS

NO8 NO16 NO30 NO50 NO100 NO200

PCT (-)
NO200

166

36

85

NA

NA

NA

MUCK DATA	DRY UNIT WT PCF	MOISTURE PCT	IN.SIZE	PER CENT HY WEIGHT BETWEEN SCREENS	DRY WT PCF	COMPR STRNTH KPSI	RAD PCT EST	SHORE MOH	HARDNESS SCHEMIDT
89	6.1	0.0	3.0	0.0	9.2	24.7	22.8	11.5	6.8

8.0 4.9 2.7 1.2 7.6 8.6

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUND E=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

PE PI PI PR S S S

POT VOL CHANGE (-)0.056 IN.SIZE	Liquid limits PCT	ELASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX PCT	TOUGHNESS INDEX PCT
0	20.10	16.68	16.37	3.42	6.10	0.56

(-)0.75 IN.SIZE SPFCIF GRAVITY	ANGLE/REPOSE 1 IN. DROP DEGREES AT 5.8 PCT MOIST	MATERIAL SIZE (-)12.0 ANGLE/REPOSE 10 IN. DROP DEGREES AT 5.8 PCT MOIST	APPARENT COHESION STEEL PLATE DEGREES AT 5.8 PCT MOIST	BULK DENSITY PSF AT 5.0 PCT MOIST	ANGLE INTER FRICTION DEGREES AT 5.0 PCT MOIST
2.93	32	30	30	110	33

MIL-2 CURRENT: 1 SEPT. 1972

KEY

37A
TUNNEL DATA

TUNNEL	SHAPE	GRADE	CFM	PRESS	EXHST	SIZE	H ²	18IN	GPM	AIR	WATER	PUMP	UTILITY LINES	POWER SYSTEM
SIZE 11FT 2IN	ROUND	+0.25PCT	4K	X		25			10	6IN	1IN	6IN		PRIMARY 4680V SECONDARY 440V
HAULAGE SYSTEM														
MUCK RAIL, 24IN GAGE STDN MOTORS	PERSONNEL			SUPPLY RAIL		SUPPORT SYSTEM	BOLT • TYPE	SIZE	ROOF PLATE OCCASIONAL PINNED STEEL LAGGING				SET SIZE • SHAPE 4IN H RING SETS IN FAULT ZONES	SHOTCRETE

MACHINE EXCAVATION

MACHINE	CUTTERS•MAKE•TYPE•DIAM.	CUTTING EDGES	RPM	THROU.F. • MAX/OPERATE	THRUST • MAX/OPERATE									
MAKE JARVA	MODEL 11-1100	WT 65 1DMS	CENTER 1 REED STEEL CONE, 5 DISC	INTERIOR 2Z REED STEEL TRIPLE DISC	GAGE 4 REED STEEL TRIPLE DISC	HEAD • CENTER 9.3 INTEG	HEAD KFTLB							

ANCHOR PRESS	MUCK SYSTEM BUCKET FROM FACE • 18IN CONVEYOR TO REAR	POWER SYSTEM 6-50HP MOTORS FOR HEAD. 1-40HP MOTOR HYDRAULICS	GUIDANCE LASER	THRUST/SQ FT KLB 6.09
KLG 1650				

CONVENTIONAL EXCAVATION

MACHINE JUMBO MACHINES	ROUND, NO. HOLES DEPTH DIAM. CUT.	BLASTING	MUCKING	GUIDANCE
FEED LENGTH				

KFY IDENTIFICATION
38 MILWAUKEE
SAMPLE NO
MIL-3

ROCK PROPERTIES
SEDIMENTARY: LIMESTONE
FINE GRAINED. GREY
SAMPLE NO
MIL-3

DRY WT PCF	DRY WT PCF	DRY WT PCF	DRY WT PCF
164	24	81	

MUCK DATA
DHY UNIT MOISTURE PCT(+)6 IN.SIZE 6IN. 3IN. 2IN. 1IN. 1/2IN.
WT PCF PCT IN.SIZE NO4 NO8 NO16 NO30 NO100 NO200
79 5.1 0 0 25.4 32.7 17.4 4.3 3.1 2.0 1.2 0.6 0.5 12.8

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

PE PI PI PA S S S

POT VOL CHANGE (-),0.056 IN.SIZE	LIQUID LIMIT PCT	PLASTIC LIMIT PCT	ATTERBERG LIMITS..SIZE(-) 0.056IN.	0.056IN.	FLRN INDEX	TOUGHNESS INDEX
0	15.20	14.40	12.95	0.80	3.50	0.22

(-10.75 IN.SIZE SPECIFIC GRAVITY	ANGLE/REPOSE IN IN DROP DEGREES AT 2.5 PCT MOIST	MATERIAL SIZE(-)12.0 IN.	ANGLE/SLIDE 10 IN UPR DEGREES AT 2.5 PCT MOIST	APPARENT COHESION PSF AT 2.3 PCT MOIST	BULK DENSITY PCF AT 0.0 PCT MOIST	ANGLE INTER FRICTION DEGREES AT 2.3 PCT MOIST
2.79	36	32	32	60	95	36

CURRENT: 1 SEPT. 1972

MIL-3

KEY
384
TUNNEL

TUNNEL	VENTILATION	WATER INFLOW	UTILITY LINES	POWER SYSTEM
SIZE 1FT. 2 IN.	SHAPE ROUND	GRADE +0.2PCT	CFM 4	PRESS EXST X
				SIZE 18IN 25
				HP MINOR
				AIR WATER PUMP 6IN IIN 6I N
MANAGEMENT SYSTEM				
MUCK RAIL	PERSONNEL RAIL	SUPPLY RAIL	BOLT TYPE SIZE NONE	SET SIZE SHAPE SHOTCRETE
24IN GAGE 51 MOTOR				

MAGNETIC SUSCEPTIBILITY

MACHINERIE	MAKE	MODEL	CUTTERS, MAKE & TYPE, U.I.A.M., CUTTING EDGES	RPM	TORQUE, MAX/OPERATE	THRUST, MAX/OPERATE	
JANWA	JANWA	11-1108	WT CENTER 1 REED OK-1	INTERIOR 22 REED 2K3	HEAD, CENTER 9-3	HEAD CENTER KFTLB KFTLB119 KFTLB	KLB KLB KLB KLB 639

GUIDANCE SYSTEMS FOR TWIN-STEERED VEHICLES

KLB KLB
BUCKETS TO RENT
6-50HP MOTORS NATIVE MEAD
LASER KLB

CONVENTIONAL EXCAVATION

FEEO LENGTH
MACHINE
JUMBO
MACHINES

EXPLOSIVES.
POWER FACTOR
TOTAL LBS.
PRIMERS.
TRIM
INTERIOR
CUT
LIFTERS

31

CURRENT: 09/01/12

KEY IDENTIFICATION
39 MT GREEN
SAMPLE ND
EVG-I

ROCK PROPERTIES
SEDIMENTARY: LIMESTONE
FINE GRAINED, LIGHT
GRAY

HUCK DATA
DRY UNIT
WT PCF
WET PCF
PCT IN SIZE

PCT(+)16
6IN. 3IN. 2IN. 1IN. 1/2IN.
NO^a NO8 NO16 NO30 NO50 NO100 NO200

168 26 100
94 3.8 0 0 3.2 26.6 22.1 21.5 4.3 3.7 3.3 2.0 2.2 2.4 8.7

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUND P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

P P P P PA A A A

POT VOL CHANGE (-10.055)	IN SIZE	LIQUID LIMIT PCT	PLASTIC LIMIT PCT	SHRINKAGE INDEX PCT	ATTENBERG LIMITS INDEX PCT	SIZE (-) 0.056 IN. PLASTICITY INDEX PCT	FLOW INDEX PCT	TOUGHNESS INDEX
0	15.10	13.69	11.57	1.41	3.0	0.47		

(-)0.75 IN. SIZE SPECIFIC GRAVITY	MATERIAL SIZE (-) 2.0 IN. ANGLE/REPOSE 1 IN DROP DEGREES AT 3.1 PCT MDIST	APPARENT COHESION STEEL PLATE 10-IN DROP DEGREES AT 3.1 PCT MDIST	BULK DENSITY PSF AT 3.0 PCT MOIST	ANGLE INTER FRiction DEGREES AT 3.0 PCT MDIST	SIZE (-) 12.0 IN. ANGLE INTER FRiction DEGREES AT 3.0 PCT MOIST
2.81	37	31	31	70	104

EVG-I CURRENT: 1 SEPT. 1972

三

39A
TUNNEL DATA

MANUFACTURER'S MANUAL

MACHINE	CUTTERS, MAKE, TYPE, /&AM, CUTTING EDGES	RPMS	TORQUE, MAX/OPERATE	THRUST, MAX/OPERATE
MAKE ROBBINS	WT 105-144	W/T 75 TONS	CENTER INTERIOR 3 ROBBINS 11 IN DIA DISC	GAGE 6 ROBBINS 12 IN DIA DISC
MODEL 105-144			HEAD+CENTER HEAD 5	HEAD KFTLB KFTLB
				KFTLB KFTLB
ANCHOR PRESS KLB	MUCK SYSTEM HCKET TO BELT	POWER SYSTEM 4-100 HP MOTORS DRIVE HEAD	GUIDANCE LASER	THRUST/SQ FT KLB

EXCAVATION METHODS

MACHINE	JUMBO MACHINES	FEED LENGTH	BLASTING	MUCKING	OUTLINE
RUNNO.	NO. MOLES		EXPLOSIVES,		
	DEPTH		POWDER FACTOR		
	DIAM.		TOTAL LBS		
	CUT.		PRIMERS.		
			TRIM		
			INTERIOR		
			CUT		
			ITTERS		

EVG-1 CURRENT: OZONE SITE

CURRENTS OF RESEARCH

KEY IDENTIFICATION
40. WT GREEN
SAMPLE NO
EVG-2

ROCK PROPERTIES
SEDIMENTARY: LIMESTONE
FINE GRAINED, LIGHT
GREY

DRY UNIT MOISTURE PCT(%)
WT PCF PCF 1K SIZE 6IN. 3IN. 2IN. 1IN.
1/2IN. NO4 NO8 NO16 NO30 NO50 NO100 NO200
NA NA NA NA NA NA NA

MUCK DATA
DRY UNIT MOISTURE PCT(%)
WT PCF PCF 1K SIZE 6IN. 3IN. 2IN. 1IN.
1/2IN. NO4 NO8 NO16 NO30 NO50 NO100 NO200
PCT (%)
94 2.5 0 0 2.2 24.2 26.7 17.8 4.8 3.0 3.0 2.3 3.4 2.9 9.5

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDEO P=PLATTY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

POT VOL CHANGE
(-) IN.SIZE
LIQUID LIMITS
PCT

ATTERBERG LIMITS
PLASTIC LIMIT
PCT

SIZE (-) IN.
SHRINKAGE
LIMIT
PCT

IN. PLASTICITY
INDEX
PCT

TOUGHNESS
INDEX
INOEX

IN. APPARENT ANGLE/SLIDE
ANGLE/EPOSE 10 IN UROP
1 IN DROP STEEL PLATE
DEGREES AT DEGREES AT
PCT MOIST PCT MOIST

SIZE (-) IN.
BULK DENSITY
PCF AT
DEGREES AT
PCT MOIST

EVG-2 CURRENT: 1 SEPT. 1972

KEY

40A
TUNNEL DATA

TUNNEL	VENTILATION	WATER INFLOW	UTILITY LINES	POWER SYSTEM
SIZE 10 FT 4 IN	GRADE +0.2PCT	CFM 18	PRESS X	EXHST 30 IN 40

HAULAGE SYSTEM

MUCK RAIL	PERSONNEL RAIL	SUPPLY RAIL	BOLT TYPE	SIZE	ROOF PLATE	SHOOTER
4CY CARS			NONE			

ST MOTOR

24 IN GAGE

54 LB RAIL

MACHINE EXCAVATION

MACHINE	CUITERS, MAKE, TYPE, DIA.	CUTTING EDGES	THROTTLE, MAKE/OPERATE	THROTTLE, MAKE/OPERATE
MAKE ROBBINS	CENTER 3 ROBBINS 11 IN OIA	INTERIOR 21 ROBBINS 12 IN DIA DISC	HEAD, CENTER 471LB 471LB	HEAD, CENTER 471LB 471LB

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
KLB	BUCKET TO BELT	4-100 HP MOTORS DRIVE HEAD	LASER	KLA

CONVENTIONAL EXCAVATION

MACHINE JUMBO MACHINES	ROUND, NO. HOLES DEPTH DIA. CUT,	BLASTING	HACK, %	GUIDANCE
FEED LENGTH				

EXPLOSIVES,
POWER FACTOR
TOTAL LBS
PRIMERS,
TRIM
INTERIOR
CUT
LIFTERS

KEY IDENTIFICATION
41 LAYOUT
SAMPLE NO
LAY-1

ROCK PROPERTIES
SEDIMENTARY: SANDSTONE MEDIUM
GRAINED, LIGHT BROWN TO RED,
MASSIVE. PDMDS, POORLY
CEMENTED.

MUCK DATA
DRY UNIT MOISTURE PCT(1)6 IN.SIZE
WT PCF WT PCF 1/2IN. 3IN. .2IN. 1IN.
PCT IN.SIZE 0.06 PER CENT BY WEIGHT BETWEEN SCREENS
NO4 ND16 ND30 ND50 NO100 NO200
PCT (-)
ND200

	105	4.1	0.0	7.6	7.5	5.7	12.0	12.6	4.6	3.4	2.7	1.8	15.4	1.0	25.7
--	-----	-----	-----	-----	-----	-----	------	------	-----	-----	-----	-----	------	-----	------

SHAPE OF FRACTIONN BETWEEN SCPPEN SIZES
A=ANGULAR S=SUBANGULAR R=ROUNDDED P=PLATT C=CUBIC I=IRREGULAR E=ELONGATED SP=SPhEROID

P1 P1 P1 A A A A A

POT VOL CHANGE
(-)0.656 IN.SIZE
LIQUID LIMIT
PCT
21.20 17.06 15.17 3.14 6.00 0.52

ATTERBERG LIMITS..SIZE (-) 0.056 IN...
PLASTIC LIMIT
PCT
0

SHRINKAGE
LIMIT
PCT

FLOW INDEX
INDEX
PCT

TOUGHNESS
INDEX
INDEX

SIZE (-)12.0 IN...
ANGLE/REPOSE
1 IN DROP
DEGREES AT
3.6 PCT MOIST
MATERIAL SIZE (-)12.0 IN...
ANGLE/REPOSE
10 IN WDP
DEGREES AT
3.6 PCT MOIST
ANGLE/SIDE
STEEL PLATE
DEGREES AT
3.6 PCT MOIST
IN...
APPARENT
COHESION
PSF AT
3.6 PCT MOIST
BULK
DENSITY
PCF AT
3.6 PCT MOIST
SIZE (-)12.0 IN.
ANGLE INTER
FRICTION
DEGREES AT
3.6 PCT MOIST

	2.66	37	35	27	210	97.4	38
--	------	----	----	----	-----	------	----

LAY-1 CURRENT: 1 SEPP. 1972

KEY

A

TUNNEL DATA

TUNNEL	VENTILATION	WATER INFLOW	UTILITY LINES	POWER SYSTEM
SIZE 12FT 11IN	GRADE +0.125PCT15-17K CFM PRESS EXHST X	SIZE 36IN HP 10.3 GPM 20-100	AIR WATER 6IN 3.5IN 8IN	PRIMARY 7300V SECONDARY 480V
HAULAGE SYSTEM		SUPPORT SYSTEM		
MUCK RAIL 24IN GAGE 65LB RAIL. 10TON MOTORS 10 CY CARS	PERSONNEL RAIL	SUPPLY RAIL	BOLT TYPE SIZE 3/4IN X 7FT. 10PC	SHOTCRETE SET SIZE SHAPE 4IN H RINGS AT 4FT

MACHINE EXCAVATION

MACHINE	CUTTERS, MAKE, TYPE, DIAM, CUTTING EDGES	RPM	TORQUE, MAX/OPERATE	THRUST, MAX/OPERATE
MAKE ROBBINS 141-027	WT 125 TONS	CENTER 1 ROBBINS 11IN STEEL TRIPLE DISC	HEAD, CENTER 2 1/2 ROBBINS 11IN. STEEL DISC	HEAD 5.2 INCHES OR 2.6
KLB 1000	FACE 30IN CONVEYOR TO REAR	FOR HEAD	KFTLB NA KFTLB KFTLB 8498AV	KLB 900 KLB 357AV

CONVENTIONAL EXCAVATION

MACHINE	ROUND, NO. HOLES DEPTH DIAM. CUT.	BLASTING	HUCKING	GUIDANCE
JUMBO MACHINES				
FEED LENGTH	EXPLOSIVES, POWDER FACTOR TOTAL LBS PRIMER'S, TRIM INTERIOR CUT LIFTERS			

KEY IDENTIFICATION
42 LAY ROCK PROPERTIES
SEDIMENTARY: CONGLOMERATE
WELL GRADED CORBLES TO
PEBBLES OF QUARTZITE
POORLY CEMENTED WITH
REDDISH BROWN SANDSTONE

SAMPLE NO
LAY-2

MUCK DATA
DRY UNIT MOISTURE PCT. 16
WT PCF IN. SIZE 6IN. 3IN. 2IN. 1IN.
PCT. 100 3.3 0 0 0 6.0 30.0 23.0 8.0 6.0 4.0 2.0 4.5 12.5

PER CENT BY WEIGHT BETWEEN SCREENS.....
NO16 NO18 NO30 NO50 NO100 NO200 NO200

PCT (-)

NO200

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUND PE=PLATT C=CUBIC I=IRREGULAR E=ELONGATED SP=SUPERIOR

P P-A A A A A A

POT VOL CHANGE
(-) 0.056 IN SIZE
LIQUID LIMIT PCT
0 15.00 14.18 13.80 0.82 4.00 0.21

PLASTIC LIMIT PCT
0 15.00 14.18 13.80 0.82 4.00 0.21

ATTERBERG LIMITS...SIZE (-) 0.056 IN
SWELLAGE PLASTICITY INDEX
LIMIT PCT
0 15.00 14.18 13.80 0.82 4.00 0.21

TOUGHNESS INDEX
PCT
0 15.00 14.18 13.80 0.82 4.00 0.21

SIZE (-) 12.0 IN...
ANGLE/ROSE
10-IN. DROP
DEGREES AT
3.4 PCT MOIST
0 2.65 38 32 32 15 28 39

APPARENT COHESION
STEEL PLATE
DEGREES AT
3.4 PCT MOIST
3.0 PCT MOIST 0.0 PCT MOIST
0 2.65 38 32 32 15 28 39

BULK DENSITY
PSF AT
3.0 PCT MOIST 0.0 PCT MOIST
0 2.65 38 32 32 15 28 39

LAY-2 CURRENT: 1 SEPT. 1972

KEY

42A

TUNNEL DATA

TUNNEL	VENTILATION			WATER INFLOW	UTILITY LINES	
SIZE 12 FT 11 IN	SHAPE ROUND	GRADE •0.125PCT15-7K	PRESS EXHST X	SIZE 36IN 100	HP 20-100	AIR WATER PUMP 6IN 3.5IN 8IN
HAULAGE SYSTEM						
MUCK RAIL 10 CY CAPS 10F MOTOR 24 IN GAGE 65 LB RAIL	PERSONNEL RAIL	SUPPLY RAIL	SUPPORT SYSTEM	BOLT TYPE SIZE	ROOF PLATE	SET SIZE SHAPE 4 IN F FULL RINGS IN BAD GROUND

MACHINE EXCAVATION

MACHINE	CUTTERS, MAKE, TYPE, UTM, CUTTING EDGES	RPM	TOQUE, MAX/OPERATE	THRUST, MAX/OPERATE
MAKE ROBBINS	CENTER 1 ROBBINS 11IN TRIPLE DISC	HEAD CENTER 5.2 OR 2.6	KFTLB KFTLB KFTLB491	KFTLB KFTLB KFTLB 585

ANCHOR PRESS	MUCK SYSTEM BUCKET TO BELT	POWER SYSTEM 6-10 HP MOTORS LASER DRIVE HEAD	GUIDANCE LASER	THRUST/SQ FT KLB 4.47
KLB				

CONVENTIONAL EXCAVATION

MACHINE JUMBO MACHINES	ROUNO, NO. HOLES DEPTH DIAM. CUT.	BLASTING	MUCKING	GUIDANCE
FEED LENGTH				

KEY IDENTIFICATION
43. NAVAJO
SAMPLE NO
NAV-1

ROCK PROPERTIES
SEDIMENTARY: SILTSTONE. FINE
GRAINED. GRAY. MORE THAN 33
PCT QUARTZ. 30 PCT CLAY. 10
PCT FELDSPAR. 1% PCT MICA.
CHLORITE AND GYPSUM.

MUCK DATA
DRY UNIT MOISTURE PCT(+)6 IN.SIZE 6IN. 3IN. 2IN. 1IN. 1/2IN. NO4 NO8 NO16 NO30 NO50 NO100 NO200 PCT (-) NO200

86 8.1 0.0 12.1 7.4 6.9 5.5 2.2 0.6 1.3 1.8 2.1 5.9 9.3 44.5
0.0 19.1 6.8 23.0 19.0

SCREEN ANALYSIS: UPPER LINE. DRY SCREENED (ASTM C136). AFTER WASHING (ASTM C117). LOWER LINE. SCREENED BEFORE DRYING

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SQUARE R=ROUND P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

P1 P1 PI PI AI SI S S A A

POT VOL CHANGE
(-)0.056 IN.SIZE
LIQUID LIMIT
PCT
36.8C
1.3

ATTERBERG LIMITS. SIZE (-) 0.056IN.
PLASTIC SHRINKAGE
LIMIT
PCT
23.6I
21.04
13.19
7.00
1.8C

SIZE (-) 12.0 IN.
ANGLE/REPOSE
1 IN. DROP
DEGREES AT
7.7 PCT MOIST

ANGLE/REPOSE
10 IN. DROP
DEGREES AT
7.7 PCT MOIST

ANGLE/SLIDE
STEEL PLATE
DEGREES AT
7.7 PCT MOIST

APPARENT
COHESION
PSF AT
7.5 PCT MOIST

BULK
DENSITY
PCF AT
7.5 PCT MOIST

3.13 30 30 30 340 98 36

CURRENT: 1 SEPT. 1972

NAV-1

KEY

43A
TUNNEL DATA

TUNNEL						VENTILATION			WATER INFLOW			UTILITY LINES		
SIZE 20FT 6IN	SHAPE ROUND	GRADE .005PCT	CFM 18K	PRESS EXHST X	SIZE 30IN	HP 60	SPM 1	AIR 6IN	WATER 4IN	PUMP	PRIMARY 4160V	SECONDARY 440V		
MUCK RAIL 70LB. 16CY CARS 15TON MOTOR	PERSONNEL RAIL	SUPPLY RAIL	SUPPLY RAIL	SUPPORT SYSTEM SUPPORT SYSTEM	BOLT, TYPE SIZE 3/4IN X AFT OR 10FT SET IN EPOXY	ROOF PLATE 5FT ON 13FT 16 GAGE	SET SIZE, SHAPE SET SIZE, SHAPE	SHOTCRETE TO PREVENT AIR SLACKING						

MACHINE EXCAVATION

MACHINE	MAKE	MODEL	WT	CENTER	INTERIOR	GAGE	HEAO	MAX/OPERATE	THRUST, MAX/OPERATE
ANCHOR PRESS	ORESSER	TA-205	200 TONS	4IN CHISEL 6 KERNMETAL TC PICK BITS	30 ORESSER STEEL DISC, 26 KENNMETAL TCB	6 ORESSER TC DISCS PICK BITS	\$ INTEG	KFTLB 879 KFTLB 586	KFTLB 1583 KFTLB 431
ANCHOR PRESS	JUCK SYSTEM	HUCKETS FROM FACE, 36IN CONVEYOR TO REAR	4-180MF UC MOTORS FOR HEAO 1-75HP MOTOR, HYDRAULICS	POWER SYSTEM 4-180MF UC MOTORS FOR HEAO 1-75HP MOTOR, HYDRAULICS	GUIDANCE LASER	THRUST/SQ FT KLB 1.31			

CONVENTIONAL EXCAVATION

MACHINE	ROUNO. NO. MOLES DEPTH DIAM. CUT.	BLASTING	HUCKING	GUIDANCE
JUMBO MACHINES				
FEED LENGTH				

KEY IDENTIFICATION
44 NAVAJO
SAMPLE NO NAV-2

ROCK PROPERTIES
SEDIMENTARY: SANDSTONE GRAY
MEDIUM GRAINED, MASSIVE,
FRIBLE AND POROUS. GRAINS
ANGULAR TO SUBROUNDED,
PRIMARILY QUARTZ, POORLY
CEMENTED.

DRY DRY COMPR RQD PCT (-)
WT UNIT STRENGTH SHORE MDH SCHMIDT
WT PCF PCF KPSI EST ND200
IN.SIZE IN.SIZE IN.SIZE IN.SIZE NO8 NO16 NO30 NO50 ND100 ND200
PCF PCF PCF PCF

117 LESS THAN 1.

PUCK DATA PCT(+)6 * * * * * PER CENT BY WEIGHT BETWEEN SCREENS...
DRY MOISTURE IN.SIZE 6IN. 3IN. 2IN. 1IN. NO4 NO8 NO16 NO30 NO50 ND100 ND200
WT UNIT IN.SIZE IN.SIZE

	97	9.2	0.0	0.0	0.0	1.3	2.5	2.3	11.8	23.2	12.7	10.6	7.1	29.1	
WT			0.0	0.0	0.4	12.6	19.6								
PCF															

SCREEN ANALYSIS: UPPER LINE, DRY SCREENED (ASTM C136). AFTER WASHING (ASTM C117). LOWER LINE. SCREENED BEFORE DRYING

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATE C=CUBIC I=IRREGULAR E=ELONGATED SP=SUPEREROID

A1 A1 A A1 A1 RE AI AI A

	0	18.20	16.91	16.60	1.29	4.50	0.28
POT VOL CHANGE (-)0.056 IN.SIZE							
LIQUID PLASTIC SHANKAGE PLASTICITY FLOW LIMITS LIMIT INDEX INDEX PCT PCT PCT PCT							

	2.72	31	28	32	45	99	28
10.75 IN.SIZE ANGLE/REPOSE ANGLE/REPOSE APPARENT BULK SPECIF 1 IN DROP 10 IN UROP SLIDE COHESION DENSITY GRAVITY DEGREES AT DEGREES AT PSF AT PCF AT 8.6 PCT MOIST 8.6 PCT MOIST 0.0 PCT MOIST 0.1 PCT MOIST							

Nav-2 CURRENT: 1 SEPT. 1972

KEY

44A
TUNNEL DATA

TUNNEL	SHAPE	GRADE	CFM	PRESS	EXHST	SIZE	HP	GPM	WATER INFLOW	UTILITY LINES	POWER SYSTEM
20FT 6IN	ROUND	+0.05PCT	18K	X		30IN	60	1	AIR 6IN	WATER PUMP	PRIMARY 4160V SECONDARY 440V
HAULAGE SYSTEM											
MUCK RAIL • 24IN JAGE RAIL 70LB RAIL • 16 CY CARS	PERSONNEL	SUPPLY RAIL				BOLT TYPE SIZE 1/4IN X 8FT OR 10FT SET IN	ROOF PLATE SFT OR 13FT 16 GAGE		SET SIZE SHAPE	SHOTCRETE TO PREVENT AIR SLACKING	
ISTON MOTOR						EPOXY					

MACHINE EXCAVATION

MACHINE	MAKE	MODEL	WT	CUTTERS, MAKE, TYPE, JAW, DRESSER	INTERIOR	GAGE	RPM	HEAD CENTER	TOQUE MAX/OPERATE	THRUST MAX/OPERATE
DRESSER	KL8	TH-205	200 TONS	4IN CHISEL 6 KENMETAL TC PICK BITS	30 DRESSER STEEL DISC, 20 KENMETAL TC PICK BITS	6 DRESSER TC DISC	5 INTEG	KFTLB 879 KFTLB 586	KFTLB	KLB 1583 KLB 123

ANCHOR PRESS	NUCLEUS SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
KLB 616 B	URGENIC FRCH FACE • 36IN CONVEYOR TO REAR	4 -180HP DC MOTORS FOR HEAD 1-75HP MOTOR, HYDRAULICS	L ASEH	KLB 0.37

CONVENTIONAL EXCAVATION

MACHINE	ROUND • NO. HOLES JUMBO MACHINES	BLASTING	HUCKING	GUIDANCE
FEED LENGTH	DEPTH DIAM. CUT.			

KEY	IDENTIFICATION	ROCK PROPERTIES			DRY WT PCF	COMPR STRNTH KPSI	RDD PCT	SHORE MOH SCHMIDT
45	ROCHESTER	SEDIMENTARY: SANDSTONE FINE GRAINED. BROWN TO DARK RED. MASSIVE			NA	NA	60	NA
	SAMPLE NO							
	R0-1							

MUCK DATA	DRY UNIT WT	MOISTURE PCF	PCT(+) IN.	IN. SIZE	PER CENT BY WEIGHT BETWEEN SCREENS	IN.	IN.	IN.	PCT (-)			
					6IN. 3IN. 2IN. 1IN. 1/2IN.	N04	N08	N016	N030	N050	N0100	N0200
89	4.3	0	0	2.0	9.0	12.0	13.0	15.0	4.0	2.0	3.0	11.0

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

P	E	P	E	P	A	P	A	A
---	---	---	---	---	---	---	---	---

POT VOL CHANGE (%)	IN. SIZE	ATTERBERG LIMITS	SIZE (-)	IN.	IN.	IN.	IN.	IN.
		LIQUID LIMIT	PLASTIC LIMIT	SHRINKAGE LIMIT	PLASTICITY INDEX	FLOW INDEX	TOUGHNESS INDEX	
		PCT	PCT	PCT	PCT			

(-) IN. SIZE	ANGLE/REPOSE IN. IN DROP	MATERIAL SIZE (-)	ANGLE/SLIDE STEEL PLATE	IN.	APPARENT COHESION PSF AT PCT MOIST	BULK DENSITY PCF AT PCT MOIST	ANGLE INTER FRICITION DEGREES AT PCT MOIST	IN.
SPECIFIC GRAVITY	DEGREES AT PCT MOIST		DEGREES AT PCT MOIST					

R0-1 CURRENT: 1 SEPT. 1972

KEY

**45A
TUNNEL DATA**

TUNNEL	VENTILATION	WATER INFLOW	UTILITY LINES	POWER SYSTEM
SIZE 18 FT	GRADE +0.045PCT22K	CFM X	EXHST 48 IN	HP 300
4 IN ROUND				

HAULAGE SYSTEM

MUCK RAIL	PERSONNEL RAIL	SUPPLY RAIL	SUPPORT SYSTEM
10CY CARS			
36 IN GAGE			
15T MOTOR			
50 LB RAIL			

ANCHOR PRESS

MAKE LAWRENCE	MODEL HRT	% N1	POWER SYSTEM ELECTRO-HYDRAULIC 960 HP

CONVENTIONAL EXCAVATION

MACHINE JURRO MACHINES	MUCK SYSTEM BUCKET TO BELT	POWER SYSTEM ELECTRO-HYDRAULIC 960 HP	GUIDANCE LASER	THRUST/SQ FT KLD

B-50

MAchine	CUTTERS, MAKE, TYPE, DIAM, CUTTING EDGES	RPM	TORQUE, MAX/OPERATE	THRUST, MAX/OPERATE
HEAD	INTERIOR 2" DISC AND 2" TCH ROLLER	11 30	CENTER HEAD	CENTER
TAIL	EXTERIOR 5 TBC ROLLER	KFTLB KFTLB364	KFTLB KFTLB	KLB KLB 492

CONVENTIONAL EXCAVATION

MACHINE JURRO MACHINES	ROUND, NO. HOLES DEPTH DIAM. CUT,	BLASTING	MUCKING	GUIDANCE
FEED LENGTH				

ANCHOR PRESS	MUCK SYSTEM BUCKET TO BELT	POWER SYSTEM ELECTRO-HYDRAULIC 960 HP	GUIDANCE LASER	THRUST/SQ FT KLD

EXPLOSIVES, POWER FACTOR	BLASTING	MUCKING	GUIDANCE
TOTAL LBS			
PRIMERS,			
TRIM			
TECHNIQUE			
CUT			
LIFTERS			

RO-1

CURRENT: 09/01/72

KEY IDENTIFICATION
45. WESTERN
NUCLEAR
SAMPLE NO
WNG-1

ROCK PROPERTIES
SEDIMENTARY: SANDSTONE COARSE
GRAINED. POORLY CONSOLIDATED.
ARKOSIC. WITH MINOR LAYERS OF
THIN SEAMED SILTSTONE.

	CONDMN STRENGTH WPSI	ROD PCT EST	SHORE MOH	HARDNESS..... SCHMIDT
DRY WT PCF				
125	LESS THAN 1.	30	NA	NA NA NA

32	10.5	0.0	0.0	0.0	1.0	1.0	24.9
		0.0	0.0	0.0	2.0	5.0	
		6.9	3.3	15.7	11.7		
		0.0	0.0	0.0	12.0	17.0	
		0.0	0.0	0.0	16.0	14.0	
		0.0	0.0	0.0	8.1	8.1	

SCREEN ANALYSIS: UPPER LINE. DRY SCREENED (ASTM C136). AFTER WASHING (ASTM C177). LOWER LINE. SCREENED BEFORE IRVING

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUND C=CUBIC I=IRREGULAR E=ELONGATED SP=SPEROID

A A A A A A A A

POT VOL CHANGE
(-10.056 IN. SIZE)

0 24.90 19.97 19.94 4.93 7.40

SIZE (-) 12.0 IN.	
ANGLE/REPCE	MATERIAL SIZE (-) 12.0 IN.
SPECIFIC GRAVITY	ANGLE/REPOSE IN DROP DEGREES AT 10.1 PCT MOIST
	ANGLE/SLIDE IN STEEL PLATE AT DEGREES AT 10.0 PCT MOIST
	APPARENT COHESION PSF AT 10.6 PCT MOIST
	BULK DENSITY PCF AT 0.0 PCT MOIST
	ANGLE INTER FRICTION DEGREES AT 10.6 PCT MOIST

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CURRENCE SEPTEMBER 1, 1934

KEY

46A
TUNNEL DATA

TUNNEL	SIZE	SHAPE	GRADE	CFM	PRESS EXHST	SIZE	HP	6PM 20-25	WATER INFLOW	UTILITY LINES	POWER SYSTEM
10FT X 8FT	*0.5PCT	RECT	X	5-7K	X	18IN			AIR 4IN	WATER PUMP	PRIMARY 440V SECONDARY 110V
HAILAGE SYSTEM	MUCK RAIL.	24IN GAGE RAIL	PERSONNEL RAIL	SUPPLY RAIL		SUPPORT SYSTEM HOLT. TYPE	SIZE	ROOF PLATE			

SHOTCRETE IN BAD GROUND

SET, SIZE, SHAPE

NONE

MACHINE EXCAVATION

MACHINE	MAKE	MODEL	WT	CENTER	INTERIOR	GAGE	RPM	TOQUE MAX/OPERATE	THRUST MAX/OPERATE
ANCHOR PRESS	ALPINE MINEK	F6-A	11 TONS	72 KENMETAL U MOUNTED ON TWIN	4J K PICK BITS	GAGE	HEAD CENTER 60	HEAD CENTER	HEAD CENTER

KFTLB

KFTLB

KFTLB

KFTLB

KFTLB

KFTLB

ANCHOR PRESS	MUCK SYSTEM GATHERING ARMS	POWER SYSTEM 440V ELECTRIC	GUIDANCE LASER	THRUST/SQ FT
KLB	16IN CHAIN CONV MOTORS 1IN BELT CONV. 10 REAR	50 4HP HEAD 2-20.2HP THRUST		

CONVENTIONAL EXCAVATION

MACHINE	ROUNO. NO. HOLES DEPTH	BLASTING	MUCKING	GUIDANCE
JUMBO MACHINES	DIA.M. CUT.			

FEED LENGTH

EXPLOSIVES,
POWDER FACTOR
TOTAL LAS
PRIMERS.
TRIM
INTERIOR
CUT
LIFTERS

KEY IDENTIFICATION
4.7 WESTERN
NUCLEAR
SAMPLE NO
MNG-2

ROCK PROPERTIES
SEDIMENTARY: SANDSTONE COARSE
GRAINED. POORLY CONSOLIDATED.
ARKOSIC. WITH MINOR LAYERS
OF TWIN SEALED SILSTONE.
VARYING CONCENTRATIONS OF
CARBONIFEROUS MATERIAL
REPLACED BY SILICA.

MUCK DATA
DRY UNIT
WT PCF
MOISTURE
PCT
IN. SIZE
In. SIZE
6IN. 3IN. 2IN. 1IN. 1/2IN. NO4
PER CENT BY WEIGHT BETWEEN SCREENS

125 30 NA NA NA NA

DRY WT PCF
COMPR STANTH
KPSI EST

HDR SHORE MOH SCHMIID
NO100 NO50 NO30 NO16 NO8 NO4
PCT (-)
NO200

SCREEN ANALYSIS: UPPER LINE. DRY SCREENED (ASTM C136). AFTER WASHING (ASTM C117). LOWER LINE. SCREENED BEFORE DRYING

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SQUARE R=ROUND P=PLATE C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

A E AE AE S A A A A A

POT VOL CHANGE
(-)0.05% IN. SIZE

LIQUID PLASTIC SWINKAGE
LIMIT LIMIT INDEX
PCT PCT PCT

25.25 24.74 23.37 0.51 4.00 0.13

(-10.75 IN. SIZE ANGLE/REPOSE ANGLE/SLIDE APPARENT BULK
SPECIFIC GRAVITY 1 IN DROP 10 IN DROP COMESSION DENSITY
GRAVITY DEGREES AT DEGREES AT PSF AT PCF AT
9.0 PCT MOIST 9.0 PCT MOIST 9.0 PCT MOIST 9.0 PCT MOIST
2.72 32 31 49 0 86 28

SIZE (-)2.0 IN.
ANGLE INTER
FRICITION
DEGREES AT
9.0 PCT MOIST

MNG-2 CURRENT: 1 SEPT. 1972

KEY

47A
TUNNEL DATA

TUNNEL				VENTILATION			WATER INFLOW			UTILITY LINES		
SIZE SFT X	SHAPE RECT	GRADE VARIES	CFM S-7K	PRES XAHST X	SIZE 18IN	HP	GPM OHY	2IN LIN	AIR WATER PUMP	POWER SYSTEM	SECONDARY 118W	
42IN SCRAPPER	RAIL RAIL	PERSONNEL RAIL	SUPPLY RAIL	SOLID TYPE SIZE	ROOF PLATE	SET SIZE SHAPE	SHOTCRETE					
			AIR HOIST									

MACHINE EXCAVATION

MACHINE	MAKE MODEL	WT	CENTER	INTERIOR	GAGE	RPM	HEAD CENTER	HEAD HEAD	TORQUE MAX/OPERATE	THRUST MAX/OPERATE
						KFTLB	KFTLB	KFTLB	KLB	KLB
ANCHOR PRESS	MUCK SYSTEM									

CONVENTIONAL EXCAVATION

MACHINE JUMBO MACHINES LE ROI 4000S-AIR LEG FEED LENGTH 6FT	ROUND NO. HOLES 18 DEPTH OFT OIAM. 1.5IN CUT. BURN & HOLE SF/HOLE 2.5	EXPLOSIVES. POWDER FACTOR 5.0LB/CT TOTAL LBS 50. 40PCT GELEX 2 PRIMERS. TRIM INTERIOR CUT LIFTERS	BLASTING SAFETY FUSE. CAPS	MUCKING SCRAPER TRANSIT
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KEY IDENTIFICATION
48 SAN FERNANDO
SAMPLE NO SF-1

ROCK PROPERTIES
SEDIMENTARY: SANDSTONE ARKOSIC
IRREGULARLY BEDDED, LOOSELY
CONSOLIDATED WITH LAYERS AND
LENSSES OF SILTY MUDSTONE.

DRY UNIT WT	MOISTURE PCT	PCT IN SIZE	••••• PCT (%) 6 6IN. 3IN. 2IN. 1IN. 1/2IN. 1.065 IN. SIZE	••••• PER CENT BY WEIGHT BETWEEN SCREENS NO8 NO4 NO16 NO30 NO50 NO100 NO200 ••••• PCT (%) 16.3 1.3 LESS THAN 1.	ROD PCT EST	SHORE MOH SCHMIDT	••••• HARDNESS NA NA NA NA
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MUCK DATA DRY UNIT WT	MOISTURE PCT	PCT IN SIZE	••••• PLASTIC LIMIT PCT	••••• ATTERBERG LIMITS LIQUID LIMIT PCT	••••• MATERIAL SIZE (-) 10.185 ANGLE/REPOSE 1 IN DROP DEGREES AT 14.3 PCT MOIST	ROD PCT EST	SHORE MOH SCHMIDT	••••• HARDNESS NA NA NA NA
91	18.5	0.0	0.0	0.0	16.19	11.5	14.4	12.8
					13.94	5.1	7.0	36.4

SHAPE OF FRACTIONN BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDGED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED S=Spheroid

RE SE AI AI AI AI A

POT VOL CHANGE (-) 0.065 IN. SIZE	LIQUID LIMIT PCT	PLASTIC LIMIT PCT	SHINKAGE LIMIT PCT	SIZE (-) 10.185 IN. ANGLE/SLIDE STEEL PLATE DEGREES AT 12.5 PCT MOIST	APPARENT COHESION PSF AT PCT MOIST	BULK DENSITY PCF AT PCT MOIST	SIZE (-) 10.185 IN. ANGLE INTER FRICITION DEGREES AT 13.0 PCT MOIST
0	17.75	16.19	13.94	1.56	5.8	0.27	
2.86	30	33	36		NA	NA	42

SF-1 CURRENT: 1 SEPT. 1972

KEY
48A
TUNNEL DATA

TUNNEL				VENTILATION			WATER INFLOW			UTILITY LINES			POWER SYSTEM		
SIZE 21FT	SHAPE ROUND	GRADE +0.25PCT	CFN 20K	PRESS EXIST FACE	SIZE 36IN X	HP 200	GPM 200	AIR 6IN	WATER 6IN	PUMP 6IN	PRIMARY 4160V	SECONDARY 480V	THIRD 480V		

MACHINE EXCAVATION

MACHINE			CUTTERS, MAKE, TYPE, DIA, CUTTING EDGES			TORQUE, MAX/OPERATE			THRUST, MAX/OPERATE		
MAKE ROBBINS	MODEL 221S	WT RIPPER SHIELD	CENTER HYDRAULIC SHIELD	INTERIOR OPERATED RIPPER	GAGE TOOTH	HEAD, CENTER KFTLB	HEAD KFTLB	CENTER KFTLB	HEAD KFTLB	CENTER KFTLB	HEAD KFTLB

ANCHOR PRESS kLB	HUCK SYSTEM BUCKET TO 6FT CONVEYOR TO REAR	POWER SYSTEM HYDRAULIC	GUIDANCE LASER	THRUST/SQ FT kLB

CONVENTIONAL EXCAVATION

MACHINE JUMBO MACHINES	ROUND, NO. HOLES DEPTH DIAM. CUT.	BLASTING	MUCKING	GUIDANCE
FEED LENGTH				

EXPLOSIVES,
POWDER FACTOR
TOTAL LBS
PRIMERS,
TRIM
INTERIOR
CUT
LIFTERS

KEY	IDENTIFICATION SAN FERNANDO	ROCK PROPERTIES SEDIMENTARY: SANSTONE AND BIOTITE RICH SILSTONE. POORLY TO WELL CONSOLIDATED. POORLY TO WELL SORTED.	ORY WT PCF	COMPR STRNTH KPSI	RQD PCT EST	SHORE MOH	HARNESS SCMIOT	NA	NA	NA
4-9	SAMPLE NO SF-2			142	2	50				

FUCK DAY

DRY UNIT MOISTURE PCT(+)16 *.....PER CENT BY WEIGHT BETWEEN SCREENS..... *
 WT PCF PCT IN.SIZE 6IN. 3IN. 2IN. 1IN. 1/2IN. NO4 NO8 NO16 NO30 NO50 NO100 NO200 NO200
 PCT (-)
 NO200

卷之三

SCREEN ANALYSIS: UPPER LINE. ORY SCREENED (ASTM C136). AFTER WASHING (ASTM C117). LOWER LINE. SCREENED BEFORE DRYING.

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUND O P=PLATE C=CURIC I=IRREGULAR E=ELONGATED S=SPHEROID

卷之三

POT VOL CHANGE
1510-056 - IN-SIZE

ATTERBERG LIMITS..SIZE(=) 0.056IN. PLASTICITY CEMENTUM

9 **31.5** **26.8** **21.5** **4.7** **7.6** **0.61**

SIZE(-)1.0 IN.
 ANGLE INTER
 FRICTION
 DEGREES AT
 15 PCT MOIST

(-)0.75 IN. SIZE		MATERIAL SIZE(-)1.0 IN.	APPARENT COHESION	BULK DENSITY	PCF AT
SPECIFIC GRAVITY	ANGLE/REPOSE 1 IN. OROP DEGREES AT 15.1 PCT MOIST	ANGLE/SLIDE 10 IN. DROP DEGREES AT 15.1 PCT MOIST	STEEL PLATE OEGREES AT 15.1 PCT MOIST	IS.1 PCT MOIST	PCT MOIST

27 NA
NA
NA

CURRENT: 1 SEPT. 1972

KEY

49A
TUNNEL DATA

TUNNEL	VENTILATION	WATER INFLOW	UTILITY LINES	POWER SYSTEM							
SIZE 2FT	SHAPE ROUND	GRADE +0.25PCT	CFM FACE	PRESS EXHST	SIZE 36IN	HP 20	GPM 6IN	AIR 6IN	WATER PUMP	PRIMARY 4160V	SECONDARY 480V
MUCK RAIL	PERSONNEL RAIL	SUPPLY RAIL	BOLT TYPE	SIZE	ROOF PLATE	SET, SIZE, SHAPE CONTINUOUS PRECAST CONCRETE BIN OR 10IN THICK X 4FT - 4 SEGMENT			SHOTCRETE		

HAULAGE SYSTEM

MACHINE	CUTTERS, MAKE, TYPE, OIAH, CUTTING EDGES	RPM	TORQUE, MAX/OPERATE	THRUST, MAX/OP/OPATE						
MAKE	WT	HEAD	CENTER	HEAD						
ROBBINS	WT 22TS RIPPER SHIELD	285 TONS	CENTER HYDRAULIC OPERATED RIPPER	INTERIOR GAGE TOOTH	KFTLB KFTLB	KFTLB KFTLB				

MACHINE EXCAVATION

MACHINE	CUTTERS, MAKE, TYPE, OIAH, CUTTING EDGES	RPM	TORQUE, MAX/OPERATE	THRUST, MAX/OP/OPATE						
MAKE	WT	HEAD	CENTER	HEAD						
ANCHOR PRESS	MUCK SYSTEM BUCKET TO 6FT CONVEYOR TO REAR	POWER SYSTEM HYDRAULIC	GUIDANCE LASER	THRUST/50 FT KLT						

CONVENTIONAL EXCAVATION

MACHINE	ROUND, NO. HOLES DEPTH OIAH, CUT.	BLASTING	HUCKING	GUIDANCE
JUMBO MACHINES				
FEED LENGTH				

KEY 50 IDENTIFICATION ROCK PROPERTIES
 SEDIMENTARY: MUDSTONE, DARK
 GRAY, FINE GRAINED, MASSIVE.
 SAMPLE NO. KM-1

MUCK DATA
 DRY UNIT MOISTURE PCT(+)6 IN.SIZE 6IN. 3IN. 2IN. 1IN. 1/2IN.
 WT PCT PCF IN. PCF IN. PCF IN.

61 9.4 0.0 0.0 5.9 1.9 5.2 28.9 0.3 1.3 2.7 5.4 6.3 12.5 29.6
 46.7 20.1 8.4 11.0 6.4 3.3

SCREEN ANALYSIS: UPPER LINE= DRY SCREENED (ASTM C136). AFTER WASHING (ASTM C177). LOWER LINE, SCREENED BEFORE DRYING

SHAPE OF FRACTION BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUND P=PLATE C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

PE PE PI PI A A A A A

POT VOL CHANGE (-)0.056 IN.SIZE	LIQUID LIMIT PCT	PLASTIC LIMIT PCT	ATTERBERG LIMITS SHRINKAGE LIMIT PCF	SIZE (-) 0.056IN. IN. APPARENT ANGLE/SLIDE ANGLE/REPOSE 10 IN UROP DEGREES AT DEGREES AT 12.7 PCT MOIST 12.7 PCT MOIST	FLOW INDEX PCI	PLASTICITY INDEX PCI	TOUGHNESS INDEX PCI	SIZE (-) 12.0 IN. BULK DENSITY PSF AT DEGREES AT 10.9 PCT MOIST 0.0 PCT MOIST 10.9 PCT MOIST
0 28.30 24.97 19.12 3.33 3.60 0.92								
2.87 29 28 31 37 79 35								

KM-1 CURRENT: 1 SEPT. 1972

KEY

50A
TUNNEL DATA

TUNNEL				VENTILATION				WATER INFLOW				UTILITY LINES			
SIZE	SHAPE	GRADE	CFM	PRESS	EXHST	SIZE	HP	GPM	AIR	WATER	PUMP	PRIMARY	SECONDARY	PRIMARY	SECONDARY
10FT X 9FT	RECT	+0.5PCT	5K	FACE	VENT	24IN	25	0							

HAULAGE SYSTEM

MUCK RAIL*	PERSONNEL RAIL	SUPPLY RAIL	SUPPORT SYSTEM	BOLT TYPE	SIZE	ROOF PLATE	SET SIZE	SHAPE	SETS AT 3FT OR 6FT	SHOTCRETE
45LB RAIL										

MACHINE EXCAVATION

CUTTERS, MAKE, TYPE, DIAM, CUTTING EDGES								RPM	TORQUE, MAX/OPERATE		THRUST, MAX/OPERATE	
MACHINE	MAKE	MODEL	WT	CENTER	INTERIOR	GAGE	MOUNTED	HEAD, CENTER	HEAD	CENTER	HEAD	CENTER
ANCHOR PRESS	ALPINE MINER	F6-A	11 TONS	40 IN FLIGHT CONVEYOR	43 KH PICK RITS. ON TWIL RIPPER HEADS	KLB	78	KFTLB	KFTLB	KFTLB	KFTLB	KLB

ANCHOR PRESS	HUCK SYSTEM GATHERING ARMS	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
KLB	14IN FLIGHT CONVEYOR	ELECTRIC MOTORS 50-4HP HEAD 2-20-4HP THRUST	LASER	KLB

CONVENTIONAL EXCAVATION

MACHINE	ROUND, NO. HOLES	BLASTING	MUCKING	GUIDANCE
JUMBO MACHINES	DEPTH DIAHM. CUT.			

FEED LENGTH

EXPLOSIVES,
POWDER FACTOR
TOTAL LBS
PRIMERS,
TRIM
INTERIOR
CUT
LIFTERS

APPENDIX C
SYSTEM DATA SHEETS

<u>Identification</u>	<u>Page</u>	<u>Identification</u>	<u>Page</u>
NAST-1	C-1, C-2	5-1	C-51, C-52
NAST-2	C-3, C-4	7-2	C-53, C-54
NAST-3	C-5, C-6	11-3	C-55, C-56
NAST-4	C-7, C-8	11-4	C-57, C-58
GA-1	C-9, C-10	72-1	C-59, C-60
H-1	C-11, C-12	MSU-1	C-61, C-62
H-2	C-13, C-14	MSU-2	C-63, C-64
LK-1	C-15, C-16	LAW-2	C-65, C-66
LK-2	C-17, C-18	LAW-3	C-67, C-68
LK-5	C-19, C-20	LAW-4	C-69, C-70
LK-6	C-21, C-22	MIL-1	C-71, C-72
LK-7	C-23, C-24	MIL-2	C-73, C-74
SM-1	C-25, C-26	MIL-3	C-75, C-76
CL-1	C-27, C-28	EVG-1	C-77, C-78
LK-3	C-29, C-30	EVG-2	C-79, C-80
LK-4	C-31, C-32	LAY-1	C-81, C-82
MB-1	C-33, C-34	LAY-2	C-83, C-84
MB-3	C-35, C-36	NAV-1	C-85, C-86
ST-1	C-37, C-38	NAV-2	C-87, C-88
CR-1	C-39, C-40	RO-1	C-89, C-90
HS-1	C-41, C-42	WNG-1	C-91, C-92
NY-1	C-43, C-44	WNG-2	C-93, C-94
NY-2	C-45, C-46	SF-1	C-95, C-96
QL-1	C-47, C-48	SF-2	C-97, C-98
MB-2	C-49, C-50	KM-1	C-99, C-100

C-i

APPENDIX C
SYSTEM DATA SHEETS

C-ii

ROCK DATA:

Lithology: Igneous, granite, gray, medium to fine grained, moderately to slightly fractured and jointed, 10 to 20% quartz, 50 to 60% feldspar, balance dark minerals.

Uniaxial Compressive Strength: 18 KPSI.

RQD: (Estimated) 90%.

Dry Unit Weight: 167 PCF.

Ground Water: Minor, primarily from fault zones.

Hardness: NA

TUNNEL DATA:

Size: 9' 9" diameter. Grade: (+) 0.22%.

Ventilation System: 10 KCFM, exhaust, 22" pipe to rear of conveyor, 16" to face.

Utility System: 6" air line, 2" water line, 6" pump line.

Water Inflow: 5 to 20 gpm.

Power System: 4160/480V.

Haulage System: Muck, personnel, supplies by rail cars, 36" gage, 70# rail.

Support System: 4" ring and half sets, at 4', 3' and 2' centers in bad ground, 13" wide x 10' - 16 gage plates secured by 4-1" x 7' grouted bolts as required.

EXCAVATION DATA:

Machine: Wirth Erkelenz, Hardrock Model. Weight: 67 tons.

Cutters: 25 Hughes Tool/Wirth Tungsten Carbide Button. Gage: 6-11 1/2" TCB roller. Interior: 15-11 1/2" TCB roller. Center: 2-11 1/2" roller and 2-11 1/2" TCB Cone.

Rotation: Head, 8 1/2 RPM

Torque: 150 K ft. # max., 110 K ft. # operating

Thrust: 290 K lbs.

Muck System: Bucket from face, 22" belt conveyor to rear.

Power System: 3-200 HP electric motor driven hydraulic pumps driving hydraulic motors.

Guidance System: Laser.

MUCK DATA

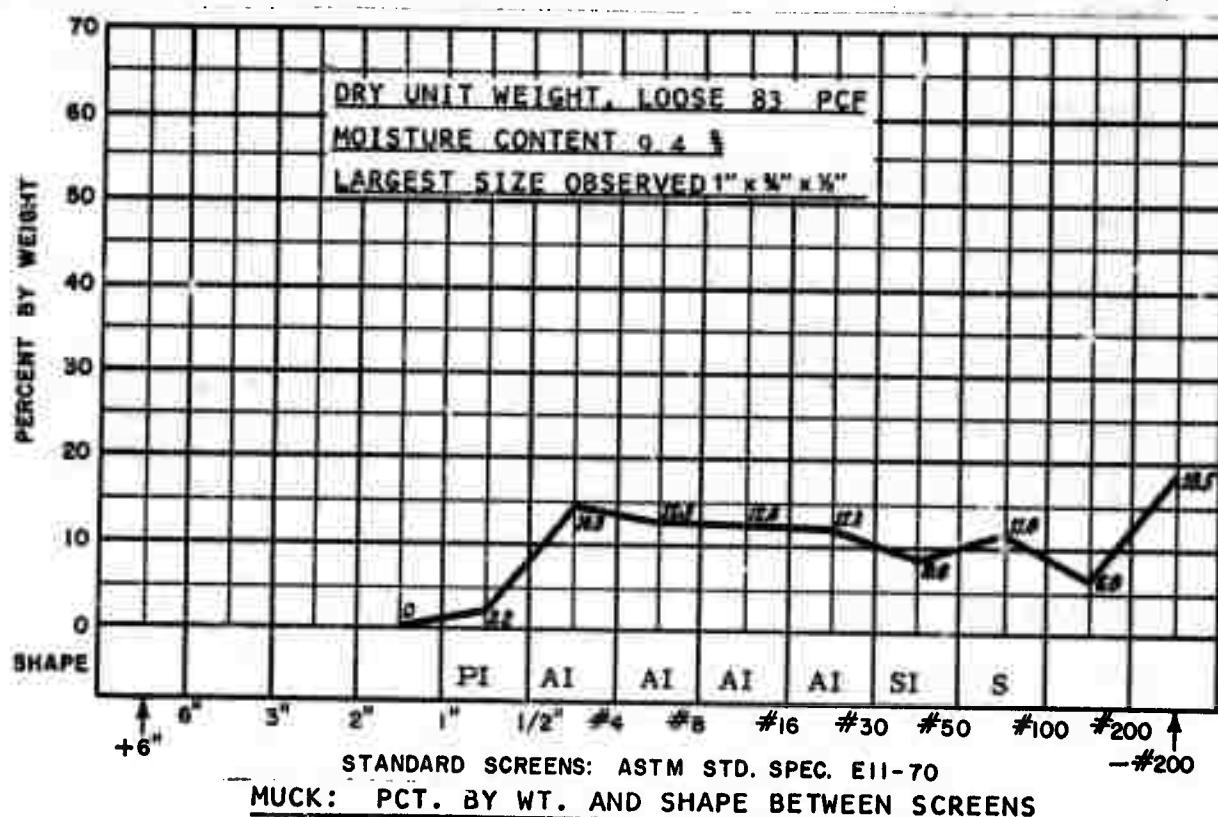
Abrasiveness N. A. Pot. Vol. Change, Material Size (-) 0.065" : 0 Spec. Gravity, Material Size (-) 0.50" : 2.69

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.185 IN.

Liquid Limit 14.50 % Plastic Limit 14.00 % Shrinkage Limit 13.50 %
Plasticity Index 0.50 % Toughness Index 0.16 % Flow Index 3.0 %

MATERIAL SIZE (-) 0.50 IN.

Angle/Repose 1" Drop @ 9.0 % Moisture, 37°	Apparent Cohesion PSF @ % Moisture, NA	Angle/Repose 10" Drop @ 9.0 % Moisture, 36°
Angle Slide Steel Plate @ 9.0 % Moisture, 41°	Bulk Density PCF @ % Moisture, NA	Angle Internal Friction @ 8.5 % Moisture, 42°



SUMMARY

Rock Class: Igneous: Granite, moderately to slightly fractured and jointed.
Medium to fine grained. High strength. RQD (Est.) 90%. DUW: 167 PCF.
Ground water: Minor. Hardness: NA

System Class: TBM, Wirth Erkelenz, Hardrock, 9'9" dia. 25 Hughes Tool/Wirth TCB roller and cone cutters. RPM: 8-1/2, 110 K ft # Torque, 290 K# Thrust. Mucking: Buckets to belt. Haulage: Rail. Support: Steel ring and half sets, rockplates and rock bolts.

MDN STUDY

9/1/72

SYSTEM DATA SHEET

MDN

Ident. No. NAST-1

Sheet 2

ROCK DATA:

Lithology: Igneous, granite, gray, medium to fine grained, moderately to slightly fractured and jointed, 10% to 20% quartz, 50% to 60% feldspar, balance dark minerals.

Uniaxial Compressive Strength: 18 KPSI.

RQD: (Estimated) 90%.

Dry Unit Weight: 167 PCF.

Ground Water: Minor, primarily from fault zones.

Hardness: NA

TUNNEL DATA:

Size: 9'9" diameter. Grade: (+) 0.22%.

Ventilation System: 10 KCFM, exhaust, 22" pipe to rear of conveyor,
16" to face.

Utility System: 6" air line, 2" water line, 6" pump line.

Water Inflow: 5 to 20 gpm.

Power System: 4160/480V.

Haulage System: Muck, personnel, supplies by rail cars, 36" gage 70# rail.

Support System: 4" ring and half sets, at 4', 3' and 2' centers in bad
ground (approximately 650'), 13" wide x 10' - 16 gage plates secured by
4-1" x 7' grouted bolts as required, (approximately 1200').

EXCAVATION DATA:

Machine: Wirth Erkelenz, Hardrock Model. Weight 67 tons.

Cutters: 25 Hughes Tool/Wirth Tungsten Carbide Button. Gage: 6-11 1/2"
TCB roller. Interior: 15-11 1/2" TCB roller. Center: 2-11 1/2" roller
and 2-11 1/2" TCB cone.

Rotation: 8 1/2 RPM

Torque: 150 K ft # max., 100 K ft. # operating.

Thrust: 290 K lbs

Muck System: Bucket from face, 22" belt conveyor to rear.

Power System: 3-200 HP electric motor driven hydraulic pumps driving
hydraulic motors and cylinders.

Guidance System: Laser.

MUCK DATA

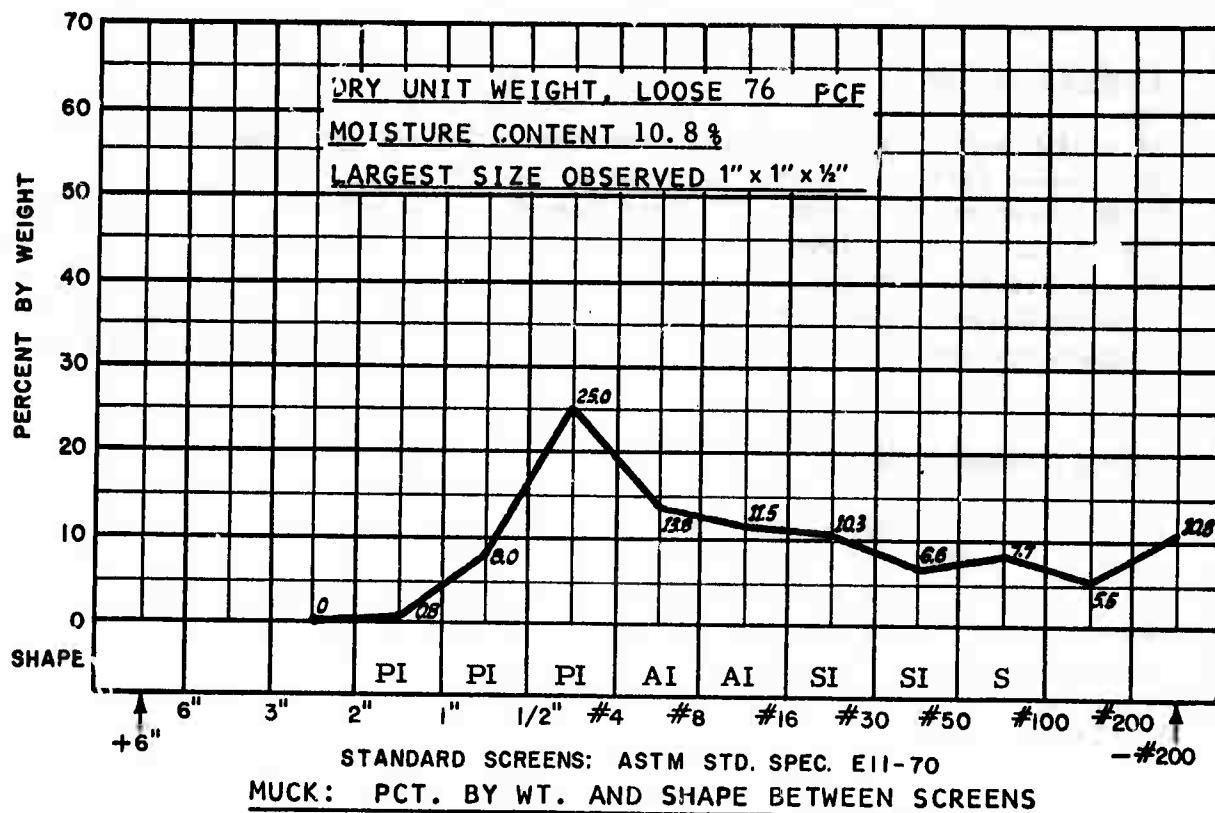
Abrasiveness N. A. Pot. Vol. Change, Material Size (-)0.056" : 0 Spec. Gravity, Material Size (-) 0.50" : 2.66

ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 19.5 % Plastic Limit 18.2 % Shrinkage Limit 17.9 %
Plasticity Index 1.3 % Toughness Index 0.28 % Flow Index 4.6 %

MATERIAL SIZE (-)1.0 IN.

Angle/Repose 1" Drop @ 8.7 % Moisture, 38°	Apparent Cohesion PSF @ % Moisture, NA	Angle/Repose 10" Drop @ 8.7 % Moisture, 38°
Angle Slide Steel Plate @ 8.7 % Moisture, 49°	Bulk Density PCF @ % Moisture, NA	Angle Internal Friction @ 8.5 % Moisture, 31°



SUMMARY

Rock Class: Igneous: Granite, medium to fine grained, moderately to slightly fractured and jointed. High strength. RQD: (Est.) 90%. DUW: 167 PCF.
Ground water: Minor. Hardness: NA.

System Class: TBM, Wirth Erkelenz Hardrock. 9' 9" dia. 25 Hughes Tool/Wirth TCB roller and tricone cutters. RPM: 8-1/2, 100 K ft # Torque, 290 K# Thrust. Mucking: Buckets to belt. Haulage: Rail. Support: 4" ring and half sets, roof plates and rock bolts.

MDN STUDY
9/1/72

SYSTEM DATA SHEET
MDN

Ident. No. NAST-2
Sheet 2

ROCK DATA:

Lithology: Igneous, biotitic granite, fine grained, with major quartz and minor feldspar and dark mineral contents.

Uniaxial Compressive Strength: 13 KPSI.

RQD: (Estimated) 90%.

Dry Unit Weight: 152 PCF.

Ground Water: Minor, from fault zones.

Hardness: NA

TUNNEL DATA:

Size: 10' high x 16' wide x 8', alcove from 9'-9" diameter tunnel.

Ventilation System: 10 KCFM, exhaust, 22" pipe.

Utility System: 6" air line, 2" water line, 6" pump line.

Water Inflow: 5-10 GPM.

Power System: Not applicable.

Haulage System: Muck, personnel, supplies by rail cars, 36" Gage, 70# rail.

Support System: 1" x 7' grouted rock bolts and 13" x 10'-16 gage roof plates.

EXCAVATION DATA:

Conventional Rail Haulage System.

Drilling: 2-S53F, 4' feed, jack legs.

Drill Round: 72 holes, 1 3/4" diameter, 9' av. depth, double V-cut.

Explosives: 300# Gelex #2-60%. Powder Factor, 6.3#/CY.

Blasting: Electrical, zero and 7 regular delays.

Mucking: Diesel front end loader, 1/2 CY.

Guidance: Not applicable.

MUCK DATA

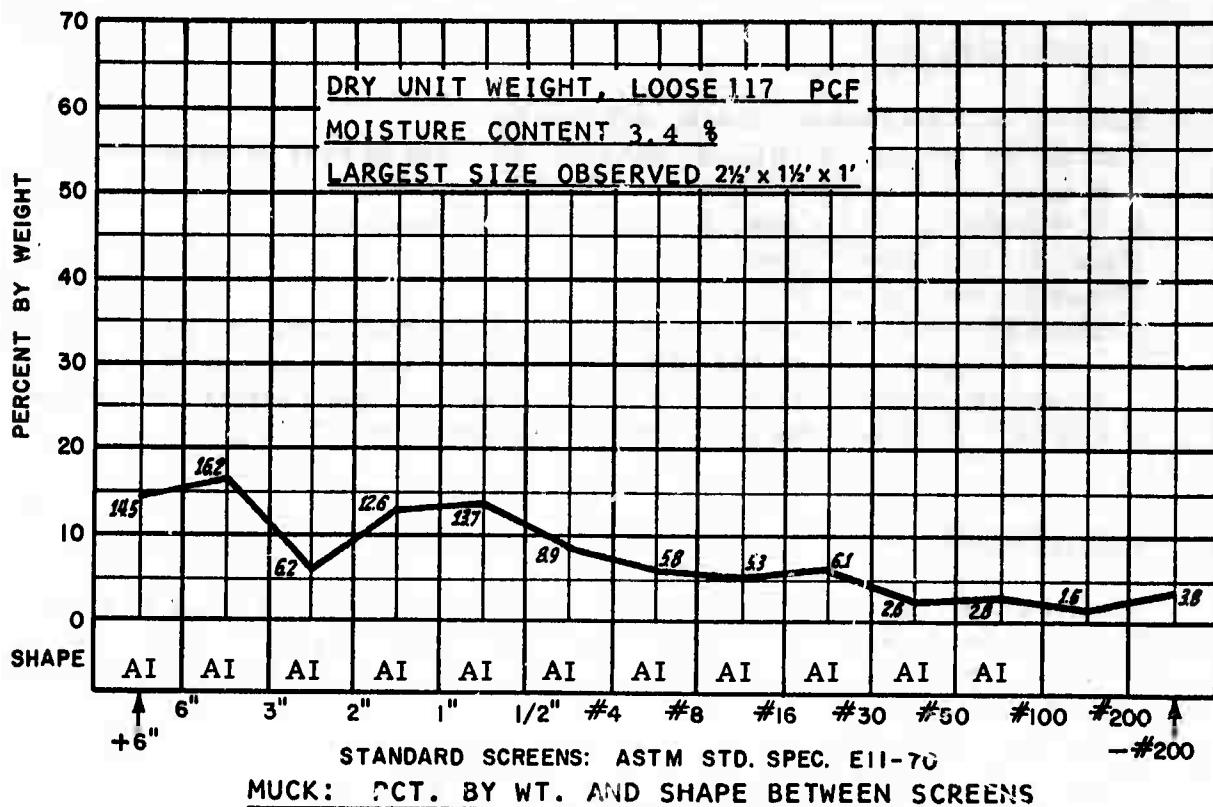
Abrasiveness Pot. Vol. Change, Material Spec. Gravity, Material
 N. A. Size (-) 0.056" : 0 Size (-) 0.75" : 2.65

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 19.50% Plastic Limit 17.41% Shrinkage Limit 17.13%
 Plasticity Index 2.09% Toughness Index 0.51% Flow Index 4.10%

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop @ 2.8 % Moisture, 39°	Apparent Cohesion PSF @ 3.0 % Moisture, 80	Angle/Repose 10" Drop @ 2.8 % Moisture, 36°
Angle Slide Steel Plate @ 2.8 % Moisture, 31°	Bulk Density, PCF @ 0.0 % Moisture, 91.2	Angle Internal Friction @ 3.0 % Moisture, 38°



SUMMARY

Rock Class: Igneous: Granite, biotitic, fine grained. Medium strength.
RQD (Est.) 90%. D UW: 152 PCF. Ground water: Minor. Hardness: NA.

System Class: Conventional Rail. 10' high x 16' wide x 8' alcove. Two jack leg drills, 72-9' holes, double V-cut. PF 6.3#/CY. Mucking: Diesel front end loader, 1/2 CY. Haulage: Rail. Support: Grouted rock bolts and roof plates.

MDN STUDY

9/1/72

SYSTEM DATA SHEET

MDN

Ident. No. NAST-3

Sheet 2

ROCK DATA:

Lithology: Igneous, granite, fine grained, moderately fractured, major quartz and minor feldspar and dark mineral contents.
Uniaxial Compressive Strength: 24 KPSI.
RQD: (Estimated) 90%.
Dry Unit Weight: 160 PCF.
Ground Water: Minor, primarily from fault zones.
Hardness: NA

TUNNEL DATA:

Size: 9'-10" diameter. Grade: (+) 0.22%.
Ventilation System: 10 KCFM, exhaust, 22" pipe to rear of conveyor, 16" to face.
Utility System: 6" air line, 2" water line, 6" pump line.
Water Inflow: 5 to 20 gpm.
Power System: 4160/480V.
Haulage System: Muck, personnel, supplies by rail cars, 36" gage 70# rail.
Support System: 4" ring and half sets, at 4', 3' and 2' centers in bad ground (approximately 650'), 13" wide x 10' - 16 gage plates secured by 4-1" x 7' grouted bolts as required, (approximately 1200').

EXCAVATION DATA:

Machine: Wirth Erkelenz, Hardrock Model (Modified)*. Weight 67 tons.
Cutters: 29 Hughes Tool Tungsten Carbide Button. Gage: 6-11 1/2" TCB roller. Interior: 19-11 1/2" TCB roller. Center: 2-11 1/2" roller and 2-11 1/2" TCB cone.
Rotation: 8 1/2 RPM.
Torque: 150 K ft. # max., 125 K ft. # operating
Thrust: 630 K lbs.
Muck System: Bucket from face, 22" belt conveyor to rear.
Power System: 3-200 HP electric motor driven hydraulic pumps driving hydraulic motors and cylinders.
Guidance System: Laser.

*Modified by replacement of original by a Hughes Tool Co. cutting head and cutters.

MUCK DATA

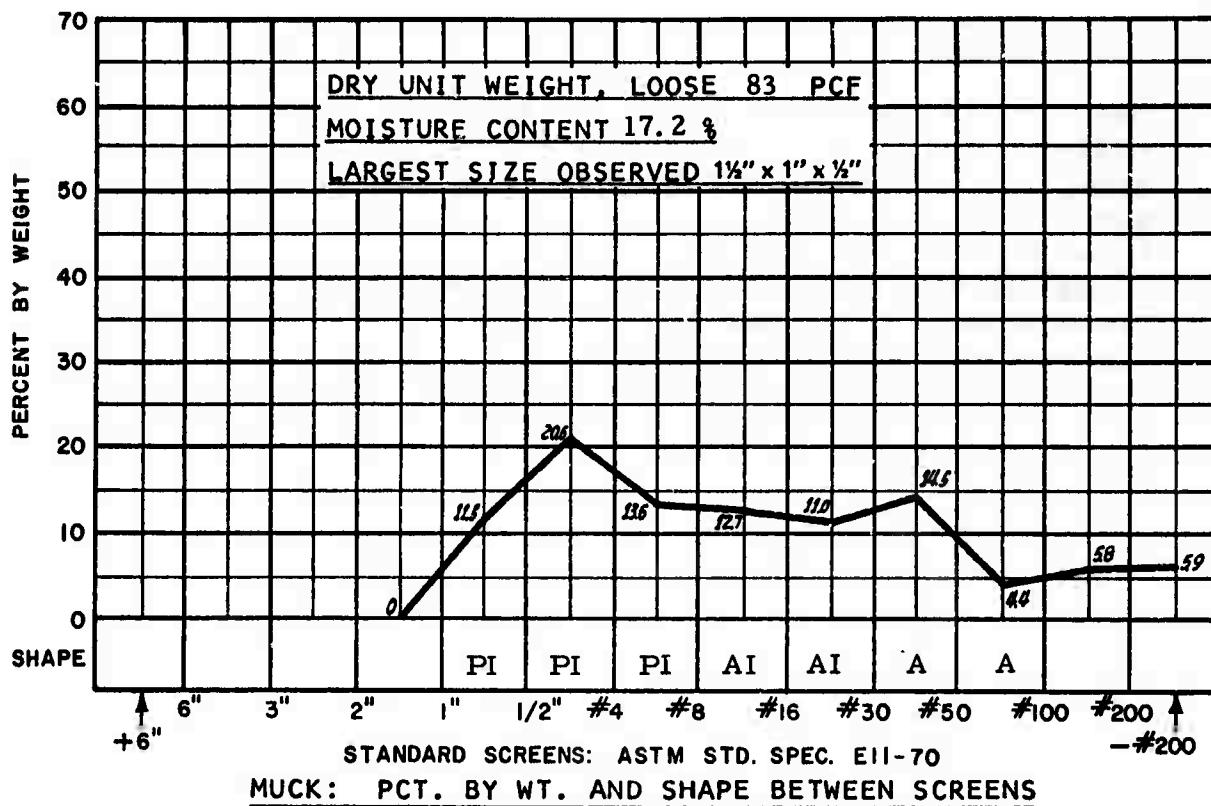
Abrasiveness Pot. Vol. Change, Material
 N. A. Size (-) 0.056 : 0 Spec. Gravity, Material
 Size (-) 0.75 : 2.64

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 19.20% Plastic Limit 18.97% Shrinkage Limit 17.50%
 Plasticity Index 0.23% Toughness Index 0.06% Flow Index 3.40%

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop @ 6.9 % Moisture, 39°	Apparent Cohesion PSF @ 7.1 % Moisture, 0	Angle/Repose 10" Drop @ 6.9 % Moisture, 34°
Angle Slide Steel Plate @ 6.9 % Moisture, 40°	Bulk Density PCF @ 0.0 % Moisture, 91	Angle Internal Friction @ 7.1 % Moisture, 33°



SUMMARY

Rock Class: Igneous: Granite, fine grained, moderately fractured. High strength. RQD (Est.) 90%. DUW: 160 PCF. Ground water: Minor. Hardness: NA

System Class: TBM, Wirth Erkelenz, Hardrock, with Hughes Tool head, 9' 10" dia. 29 Hughes Tool TCB roller and cone cutters. RPM: 8 1/2. 125 K ft # torque, 630 K# thrust. Mucking: Buckets to belt. Haulage: Rail. Support: 4" ring and half sets, roof plates and rock bolts.

MDN STUDY
9/1/72

SYSTEM DATA SHEET
MDN

Ident. No. NAST-4
Sheet 2

ROCK DATA:

Lithology: Igneous, granite, massive, major feldspar and quartz, minor dark mineral content.
Uniaxial Compressive Strength: 35 KPSI
RQD: (Estimated) 96%
Dry Unit Weight: 161 PCF
Ground Water: Minor, through fractures.
Hardness: NA

TUNNEL DATA:

Size: 10' x 10' Horse shoe. Grade (-) 0.22%
Ventilation System: 8 KCFM, exhaust, 22" pipe.
Utility System: 6" air line, 2" water line
Water Inflow: 5-10 gpm.
Power System: 110V. lighting
Haulage System: Muck and supplies: Eimco 912 diesel.
Support System: 4" WF steel sets @ 4' in 180' approx. at portal end; 1" x 7'
grouted rock bolts for approx. 35'.

EXCAVATION DATA:

Conventional Trackless System.
Drilling: Crawler Jumbo, 2-D93 Drifters, 10' feeds.
Drill Round: 48-1 3/4" holes, double V cut, 8' depth.
Explosives: 175# Gelex #2-70%. Powder factor, 6.1#/CY.
Blasting: Electrical, regular delays, zero through #10.
Mucking System: Eimco 912 diesel, front end loader.
Guidance: Transit lines.

MUCK DATA

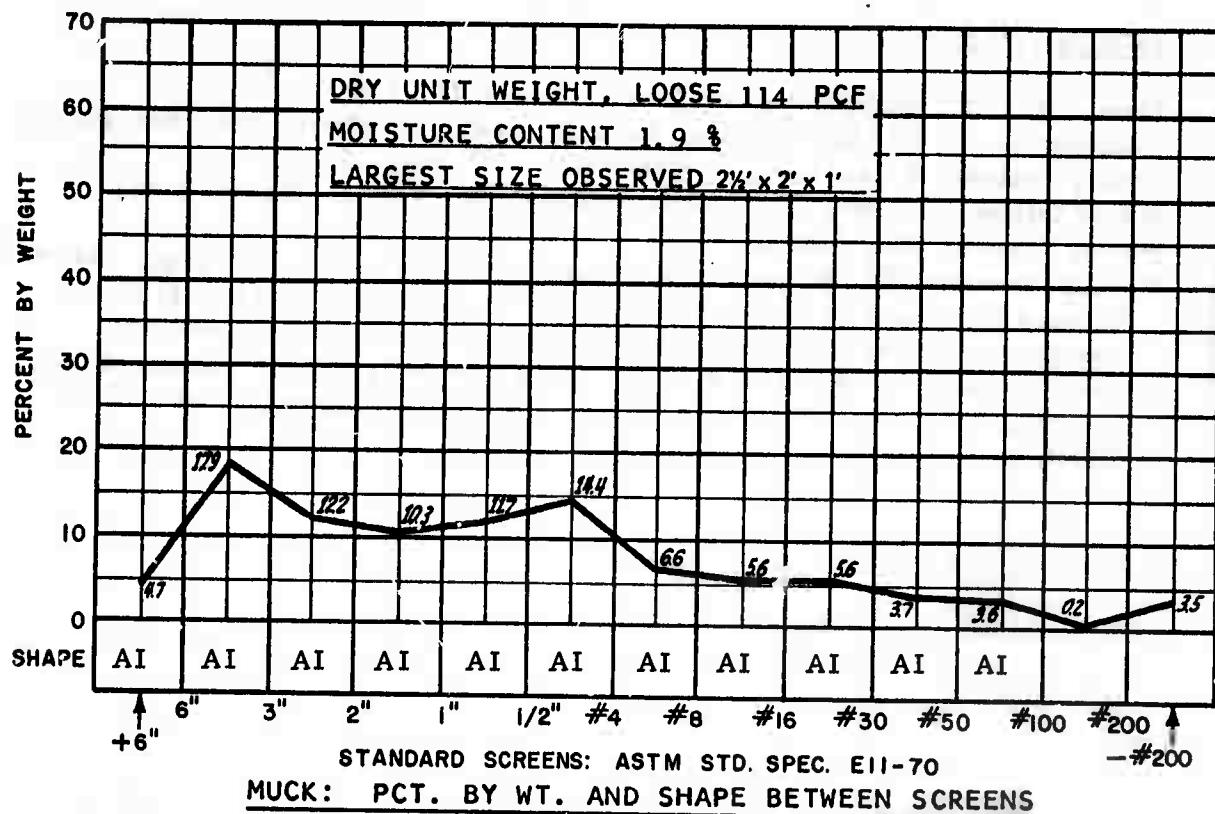
Abrasiveness N. A. Pot. Vol. Change, Material Size (-) 0.056": 0 Spec. Gravity, Material Size (-) 0.75": 2.59

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 16.20% Plastic Limit 15.78% Shrinkage Limit 13.67%
Plasticity Index 0.42% Toughness Index 0.14% Flow Index 3.00%

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop @ 0.9 % Moisture, 39°	Apparent Cohesion PSF @ 0.9 % Moisture, 215	Angle/Repose 10" Drop @ 0.9 % Moisture, 36°
Angle Slide Steel Plate @ 0.9 % Moisture, 34°	Bulk Density PCF @ 0.0 % Moisture, 106	Angle Internal Friction @ 0.9 % Moisture, 46°



SUMMARY

Rock Class: Igneous: Granite, massive, minor dark minerals. Very high strength. RQD (Est.) 96%. DUW: 161 PCF. Ground water: Minor.
Hardness: NA

System Class: Conventional Trackless. 10' x 10' arch. Two machine jumbo, 48-8' holes, V-cut. PF 6.1#/CY. Front end loader mucking and haulage.
Support: Steel sets at 4', 25%, occasional rock bolts in 730'.

MDN STUDY

9/1/72

SYSTEM DATA SHEET

MDN

Ident. No. GA-1

Sheet 2

ROCK DATA:

Lithology: Igneous, granite, gray, fine grained, moderately jointed with 1.5' to 2' bands of light tan pegmatite and laminated granite gneiss.
Uniaxial Compressive Strength: 32 KPSI.
RQD: (Estimated) 80%.
Dry Unit Weight: 162 PCF.
Ground Water: Formations generally dry.
Hardness: NA

TUNNEL DATA:

Size: 10' x 10', Modified Horseshoe. Grade: (+) 1/4%
Ventilation: 15 KCFM, exhaust, 26" dia. pipe, 125 HP at 7200' from portal.
Utility System: 8" air line, 4" water line, 10" pump line.
Water Inflow: 20 GPM. (As much as 400 GPM in occasional pockets)
Power System: 4160/440V.
Haulage System: Muck, personnel, supplies by rail cars, 36" gage, 75# rail.
Three-15T. Goodman locomotives; 2 trains of 11 to 13 cars @ 4.8 CY.
Canton car transfer at 50' to 250' from face, passing tracks @1500'.
Support System: 4" WF sets @ 4', 3' and 2' for 23%, 1" x 7' grouted bolts
for 17%, Shotcrete: 500 psi @ 18 hrs., 3750 psi @ 28 days, for 16% of
7200'.

EXCAVATION DATA:

Conventional Rail System.
Drilling: Rail mounted hydrojib jumbo, 4-CF99, & 1-CF133 drifters,
12' feed.
Drill Round: 38 holes, 1-5" center hole and 37 at 3/4" dia. Spiral Burn
Cut, 10 1/2' depth.
Explosives: 183 lbs. Gelex #2-75% x 1-1/2" dia., and 20 lbs. Smooth-
tex 70% x 7/8" dia. in upper perimeter holes. Powder factor: 5 1/2#/CY.
Blasting: Electrical, regular delays zero through 10.
Mucking: EIMCO #25, rail, air operated.
Guidance: Laser

MUCK DATA

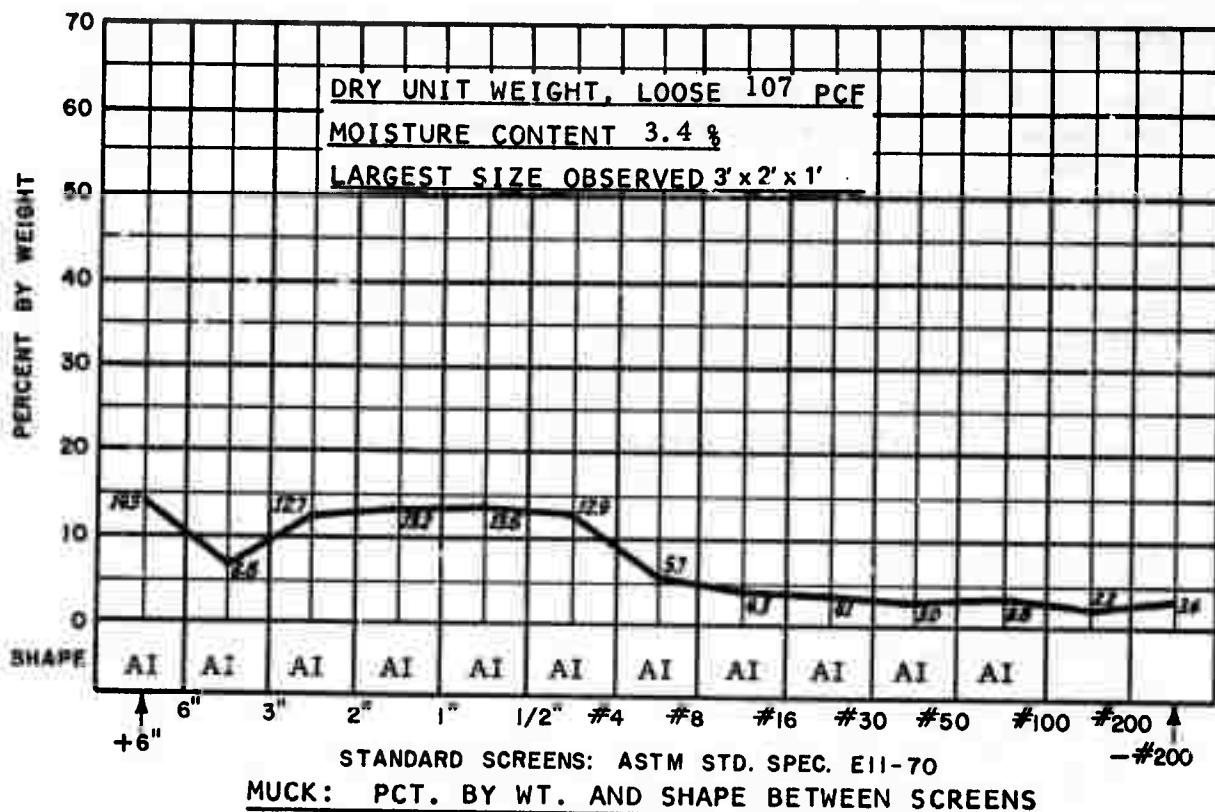
Abrasiveness N. A. Pot. Vol. Change, Material Size (-) 0.056" : 0 Spec. Gravity, Material Size (-) 0.75" : 2.70

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 18.0% Plastic Limit 17.0 % Shrinkage Limit 13.4 %
Plasticity Index 1.0 % Toughness Index 0.23 % Flow Index 4.4 %

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop @ 1.3 % Moisture, 40°	Apparent Cohesion PSF @ % Moisture, NA	Angle/Repose 10" Drop @ 1.3 % Moisture, 37°
Angle Slide Steel Plate @ 1.3 % Moisture, 32°	Bulk Density PCF @ % Moisture, NA	Angle Internal Friction @ 2.2 % Moisture, 44°



SUMMARY

Rock Class: Igneous: Granite, fine grained, with 1.5' to 2' bands of pegmatite and laminated granite gneiss. High strength. RQD (Est.) 80%. DUW: 162 PCF. Ground water: Minor. Hardness: NA.

System Class: Conventional Rail. 10' x 10' arch. Five machine jumbo, 38 10-1/2' holes, burn cut. PF 5.5#/CY. Overhead loader mucking, rail haulage. Support: Steel sets at 2' to 4', 23%, rock bolts 17%, shotcrete 16%, in 7200'.

MDN STUDY
9/1/72

SYSTEM DATA SHEET
MDN

Ident. No. H-1
Sheet 2

ROCK DATA:

Lithology: Igneous, granite, gray, gneissic, moderately jointed.
Uniaxial Compressive Strength: 39 KPSI
RQD: (Estimated) 80%
Dry Unit Weight: 164 PCF
Ground Water: Generally dry - occasional flows through fractures
Hardness: NA

TUNNEL DATA:

Size: 10' x 10' modified horseshoe. Grade: (+) 1/4%
Ventilation System: 8 KCFM exhaust, 26" pipe, 150 HP at 10,000 fpm from portal.
Utility System: 8" air line, 4" water line, 10" pump line
Water Inflow: 20-400 GPM, normal 135 GPM
Power System: 4160/480/240V.
Haulage System: Muck, personnel, supplies by rail cars, 36" gage, 75# rail.
Three-15T. Goodman locomotives, 3 trains of 5 to 7 cars @ 4.8 cy.
Canton car transfers at 50' to 250' from face, passing tracks @ 1500' to 2500'.
Support System: Minor rock bolt support for last 2500'.

EXCAVATION DATA:

Conventional Rail System
Drilling: 4 boom Hydorail jumbo, 4-CF99 + 1-CF133 drifters, 12' contin. feed.
Drill Round: 36-40 holes, 1 3/4" diameter, 11' deep, spiral burn cut with 5" center hole.
Explosives: 200 lbs. 75% Gelex #2, 25 lbs. 30% Dupont 7/8" x 24" in back holes.
Blasting: Electrical, regular delays 0-10, Powder factor 5.6#/CY.
Mucking: EIMCO #25, rail, air operated
Guidance: Laser

MUCK DATA

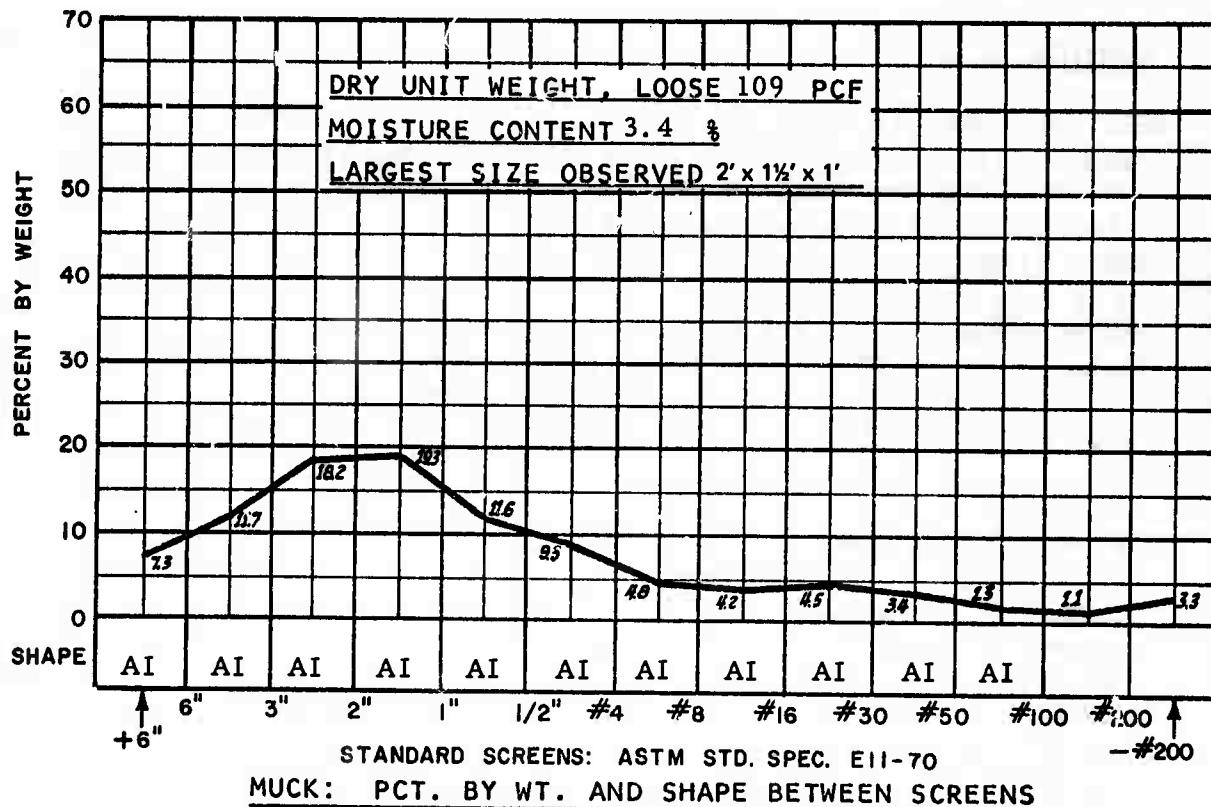
Abrasiveness N. A. Pot. Vol. Change, Material Size (-)0.056" : 0 Spec. Gravity, Material Size (-)0.75" : 2.60

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 18.10% Plastic Limit 17.95% Shrinkage Limit 11.00 %
Plasticity Index 0.15 % Toughness Index 0.04 % Flow Index 3.20 %

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop @ 3.8 % Moisture, 38°	Apparent Cohesion PSF @ 2.6 % Moisture, 30	Angle/Repose 10" Drop @ 3.8 % Moisture, 35°
Angle Slide Steel Plate @ 3.8 % Moisture, 38°	Bulk Density PCF @ 0.0 % Moisture, 105	Angle Internal Friction @ 2.6 % Moisture, 44°



SUMMARY

Rock Class: Igneous: Granite, gneissic, moderately jointed. Very high strength.
RQD (Est.) 80%. DUW: 164 PCF. Ground water: Minor. Hardness: NA

System Class: Conventional Rail. 10' x 10' arch. Five machine jumbo, 36 to 40 - 11' holes, burn cut. PF 5.6#/CY. Overhead loader mucking - rail haulage. Support: occasional rock bolts 7200' to 10,000'.

MDN STUDY

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SYSTEM DATA SHEET

MDN

Ident. No. H-2

Sheet 2

ROCK DATA:

Lithology: Igneous, biotitic quartz monzonite, fine to medium grained porphyry.
Uniaxial Compressive Strength: 25 KPSI
RQD: (Estimated) 83%
Dry Unit Weight: 162 PCF.
Ground Water: None apparent
Hardness: NA

TUNNEL DATA:

Size: 18' wide x 16' high, arched back. Grade: (+) 5 1/2%.
Ventilation System: 76 KCFM, pressure in heading, 48" pipe and tubing.
Underground fans 48", 150 HP, 2 stage. Exhaust in return airway to 3-54", 150 HP, 2 stage, surface fans.
Utility System: 6" compressed air, 2" water.
Water Inflow: None apparent.
Power System: 4160/220V for fans, 110 volt lighting.
Haulage System: Wagner ST8 Scooptram to raise, chute loaded into rail mounted skip. Personnel and supplies by diesel truck.
Support System: 13 1/2" x 9' roof plates, 6' x 3/4" rock bolts @ 4'.

EXCAVATION DATA:

Conventional Trackless System
Drilling: Gardner-Denver 3 boom jumbo, 1 PR123 and 2 DH 123 drifters, 12' feeds.
Drill Round: 47 holes, 1 3/4" diameter, including 6 hole burn cut, and 1 center hole, 4" diameter, all 10 1/2' deep.
Explosives: 25# - 1 1/2" x 8", 60% or 75% primers, 25# - 7/8" x 16", 30% in trim holes, 40# - 1 1/2" x 16", 45% in 6 hole burn cut, and 275# AN/F0 in remainder of round. Powder factor: 4#/cy.
Blasting: Electrical, regular delays, 0 through 15.
Mucking: Scooptram.
Guidance: Laser.

MUCK DATA

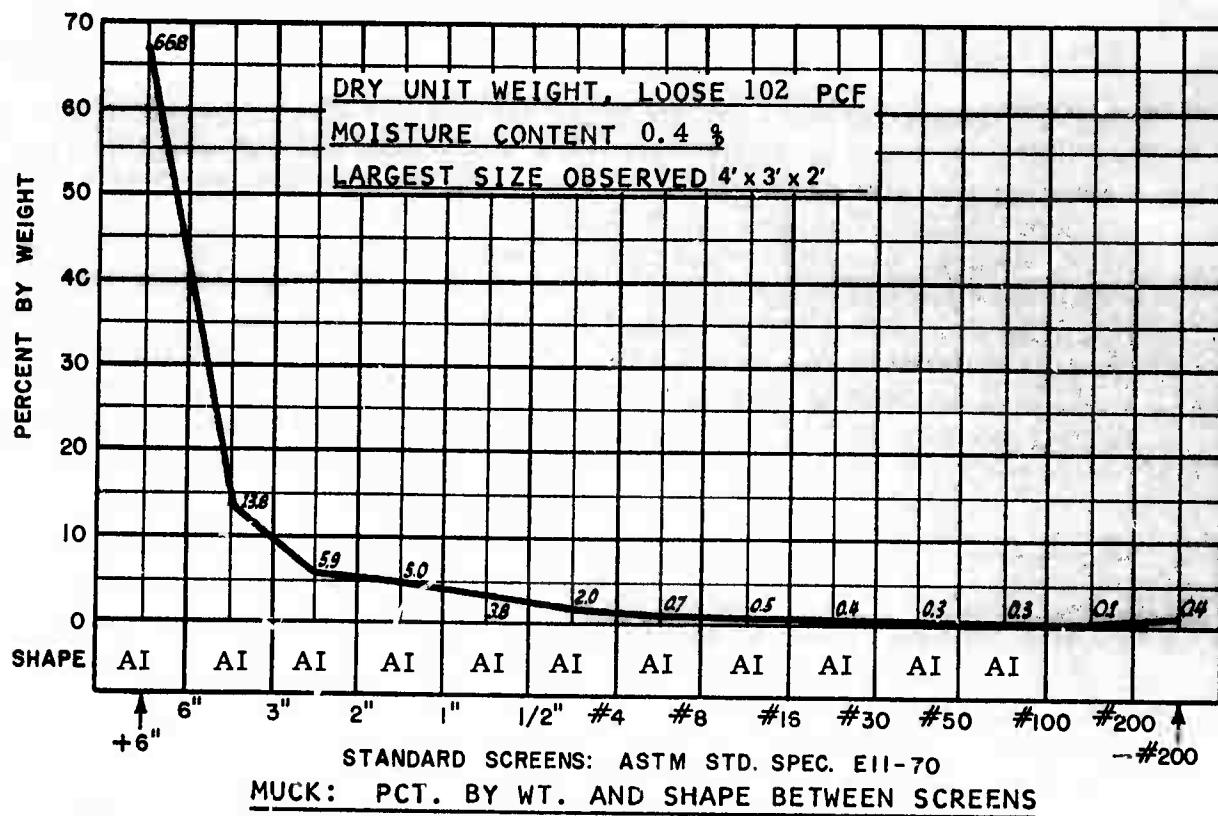
Abrasiveness Pot. Vol. Change, Material Spec. Gravity, Material
 N. A. Size (-)0.056" : 0 Size(-)0.75" : 2.85

ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 18.10 % Plastic Limit 17.98 % Shrinkage Limit 17.69 %
 Plasticity Index 0.12 % Toughness Index 0.30 % Flow Index 3.90 %

MATERIAL SIZE (-)2.0 IN.

Angle/Repose 1" Drop @ 0.8 % Moisture, 33°	Apparent Cohesion PSF @ 0.4 % Moisture, 435	Angle/Repose 10" Drop @ 0.8 % Moisture, 30°
Angle Slide Steel Plate @ 0.8 % Moisture, 29°	Bulk Density PCF @ 0.0 % Moisture, 97.3	Angle Internal Friction @ 0.4 % Moisture, 43°



SUMMARY

Rock Class: Igneous: Quartz monzonite, biotitic, fine to medium grained porphyry. High strength. RQD (Est.) 83%. DUW: 162 PCF. Ground Water: Dry. Hardness: NA.

System Class: Conventional Trackless. 18' wide x 16' arch. Three boom jumbo, 47-10 1/2' holes, burn cut PF 4#/CY. Scooptram mucking and haulage to raise-rail skip to surface. Support: Roof plates and rock bolts at 4'.

MDN STUDY
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SYSTEM DATA SHEET
MDN

Ident. No. LK-1
Sheet 2

ROCK DATA:

Lithology: Igneous, biotitic quartz monzonite, fine to medium grained porphyry, with minor steeply inclined joints.

Uniaxial Compressive Strength: 28 KPSI

RQD: (Estimated) 83%

Dry Unit Weight: 165 PCF

Ground Water: None apparent

Hardness: NA

TUNNEL DATA:

Size: 18' wide x 16' high, arched back. Grade: (+) 2%.

Ventilation System: 7.2 KCFM, pressure in heading, 48" pipe and tubing.
Underground fans 48", 150 HP, 2 stage. Exhaust in return airway to
3-54", 150 HP, 2 stage surface fans.

Utility System: 6" compressed air, 2" water.

Water Inflow: None apparent.

Power System: 4160/220 for pumps and fans, 110V lighting.

Haulage System: Wagner ST-8 Scooptram to surge pile at shaft station,
rail mounted skip to surface. Personnel and supplies by diesel truck.

Support System: 13 1/2" x 9' roof plates, 6' x 3/4" rock bolts @ 4'.

EXCAVATION DATA:

Conventional Trackless system.

Drilling: Gardner-Denver 3 boom jumbo, 3 PR123 drifters, 12' feeds.

Drill Round: 47 holes, 1 3/4" diameter, including 6 hole burn cut, and
1 center hole, 4" diameter, all 10 1/2' deep.

Explosives: 25#-1 1/2" x 8", 60% or 75% primers, 25#-7/8" x 16", 30%
in trim holes, 40#-1 1/2" x 16", 45% in 6 hole burn cut, and 275# AN/F0
in remainder of round. Powder factor: 4#/CY.

Blasting: Electrical, regular delays, 0 through 15.

Mucking: Scooptram.

Guidance: Laser.

MUCK DATA

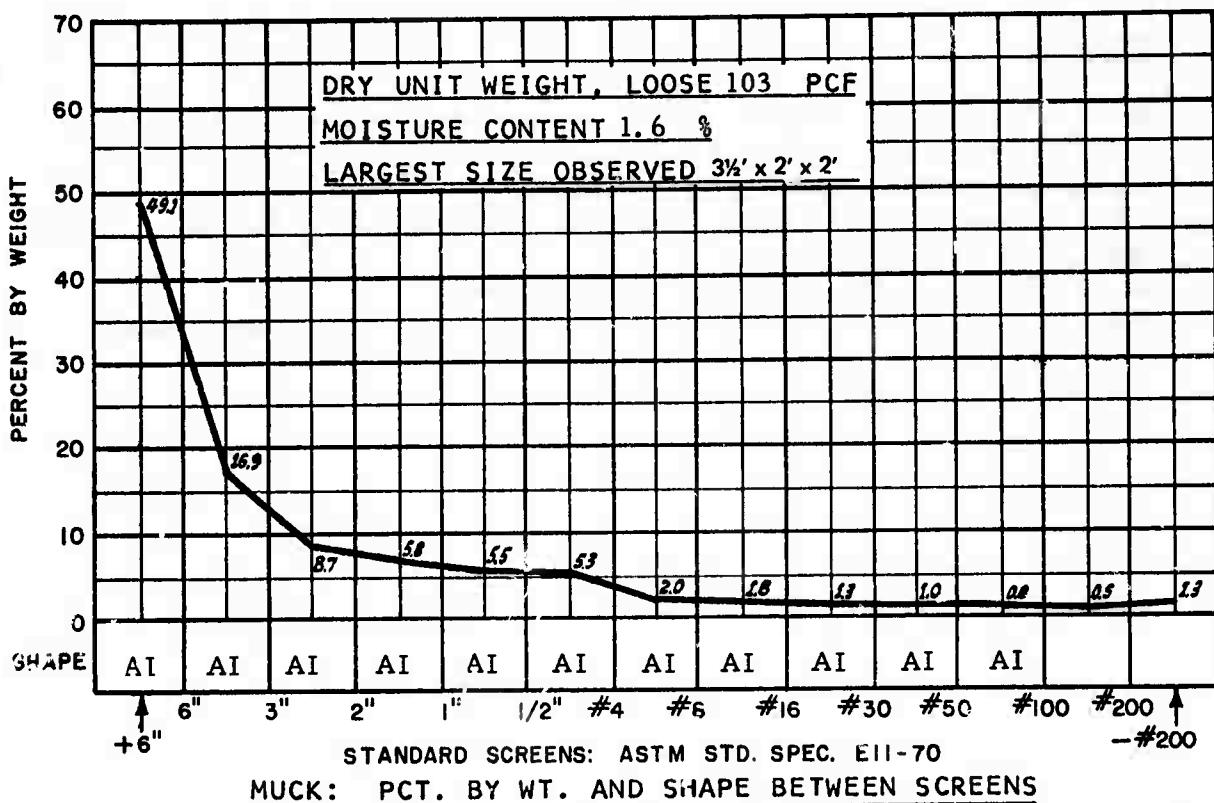
Abrasiveness Pot. Vol. Change, Material Spec. Gravity, Material
N. A. Size (-)0.056": 0 Size (-) 0.75": 2.73

ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 20.50% Plastic Limit 19.14% Shrinkage Limit 17.29 %
Plasticity Index 0.36 % Toughness Index 0.058 % Flow Index 6.2 %

MATERIAL SIZE (-)2.0 IN.

Angle/Repose 1" Drop @ 4.7 % Moisture, 43°	Apparent Cohesion PSF @ 4.9 % Moisture, 210	Angle/Repose 10" Drop @ 4.7 % Moisture, 42°
Angle Slide Steel Plate @ 4.7 % Moisture, 33°	Bulk Density PCF @ 0.0 % Moisture, 97.6	Angle Internal Friction @ 4.9 % Moisture, 39°



SUMMARY

Rock Class: Igneous: Quartz monzonite, biotitic, fine to medium grained porphyry, minor steep angle joints. High strength. RQD (Est.) 83%. DUW: 165 PCF. Ground water: Dry. Hardness: NA

System Class: Conventional Trackless. 18' wide x 16' arch. Three boom jumbo, 47 - 10 1/2' holes, burn cut. PF 4#/CY. Scooptram mucking and haulage, rail skip to surface. Support: Roof plates and rock bolts at 4'.

ROCK DATA:

Lithology: Igneous, biotitic quartz monzonite, fine to medium grained porphyry.
Uniaxial Compressive Strength: 32 KPSI
RQD: (Estimated) 92%
Dry Unit Weight: 165 PCF
Ground Water: None apparent.
Hardness: NA

TUNNEL DATA:

Size: 12' diameter vertical bore hole, reamed from 1312' to 1212' below collar, from a 13 7/8" diameter pilot hole.
Ventilation System: None in bore hole.
Utility System: 5 to 10 gpm. Water for dust suppression through pilot hole.
Water Inflow: None apparent
Power System: 440V to surface drive motors.
Haulage System: Wagner ST-8 Scooptram to surge pile at shaft station/rail mounted skip to surface.
Support System: None in bore hole.

EXCAVATION DATA:

Machine: Robbins H81R Raise Drill. Weight 49 tons. Cutters: 27 Robbins, Steel Disc. Gage: 3-12". Center: 1-11". Interior: 19-12" single and 2-11" twin. Two sets of three 12" dia. TCB roller stabilizers are installed on third points below the cutter head.
Rotation, cutter head: 6 RPM.
Torque: 260 K Foot Lbs. Full Load.
Reaming Full: Total 814K Lbs @ 2400 FSI, net 507 K#.
Muck Disposal: Scooptram, underground.
Power System: 3-440V, 100 HP motors, 1.667: 1 gathering box ratio.
Guidance System: Survey in pilot hole.

MUCK DATA

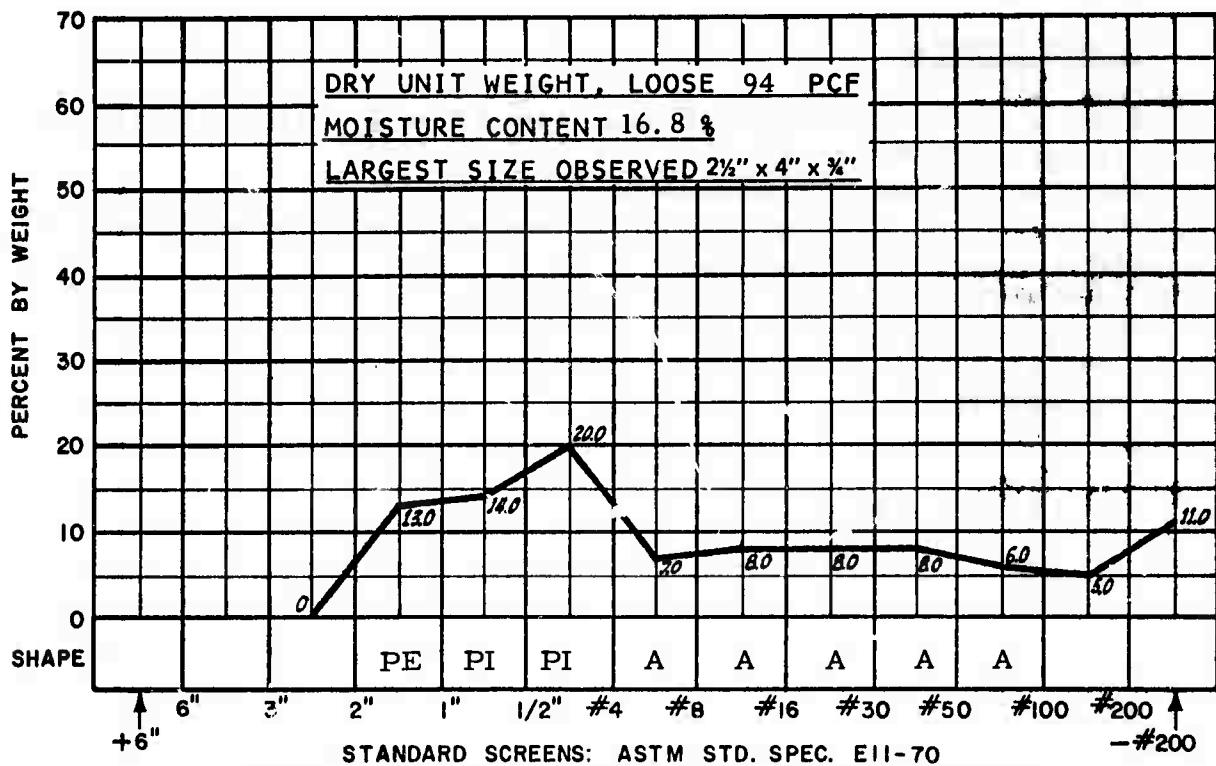
Abrasiveness N. A.	Pot. Vol. Change, Material Size (-)0.056": 0	Spec. Gravity, Material Size(-)0.056": 2.67
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ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 25.00 %	Plastic Limit 20.95 %	Shrinkage Limit 19.68 %
Plasticity Index 4.05 %	Toughness Index 0.73 %	Flow Index 5.50 %

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop @ 3.4 % Moisture, 33°	Apparent Cohesion PSF @ 3.0 % Moisture, 75	Angle/Repose 10" Drop @ 3.4 % Moisture, 32°
Angle Slide Steel Plate @ 3.4 % Moisture, 38°	Bulk Density PCF @ 0.0 % Moisture, 100	Angle Internal Friction @ 3.0 % Moisture, 37°



SUMMARY

Rock Class: Igneous: Quartz monzonite, biotitic, fine to medium grained porphyry. High strength. RQD (Est.) 92%, DUW: 165 PCF. Ground water: Dry. Hardness: NA.

System Class: RBM, Robbins H81R, 12' dia. 27 Robbins disc cutters, 6 RPM, 383.5 Kft. # torque, 507 K# pull average. Mucking and haulage: Scooptram underground, rail skip to surface. Support: None.

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SYSTEM DATA SHEET
MDN

Ident. No. LK-5
Sheet 2

ROCK DATA:

Lithology: Igneous, biotitic quartz monzonite, fine to medium grained porphyry, frequent flat angled joints.

Uniaxial Compressive Strength: (Estimated) 7 KPSI

RQD: (Estimated) 86%.

Dry Unit Weight: 137 PCF.

Ground Water: None apparent.

Hardness: N. A.

TUNNEL DATA:

Size: 4' diameter vertical bore hole reamed from 298' to 286' below collar from a 13 7/8" diameter pilot hole.

Ventilation System: Not applicable.

Utility System: 5 to 10 gpm water for dust suppression through pilot hole.

Water Inflow: None apparent.

Power System: 440V to surface drive motors.

Haulage System: Wagner ST-8 Scooptram to surge pile at shaft station/

rail mounted skip to surface. Personnel and supplies by diesel truck.

Support System: None in bore hole.

EXCAVATION DATA:

Machine: Robbins H81R Raise Drill. Weight: 49 tons.

Cutters: 11-Robbins, Steel Disc. Gage: 1-12" twin. Center 1-12" single.
Interior: 4-12" twin. Three 12" TCB roller stabilizers are installed at third points below the cutter head.

Rotation, Cutter head: 6 RPM

Torque: 260 K Foot/lbs. Full Load

Reaming Pull: Net 207K#

Muck Disposal: Scooptram underground.

Power System: 3-440V, 100 HP motors, 1.667: 1 gathering box ratio.

Guidance System: Survey in pilot hole.

MUCK DATA

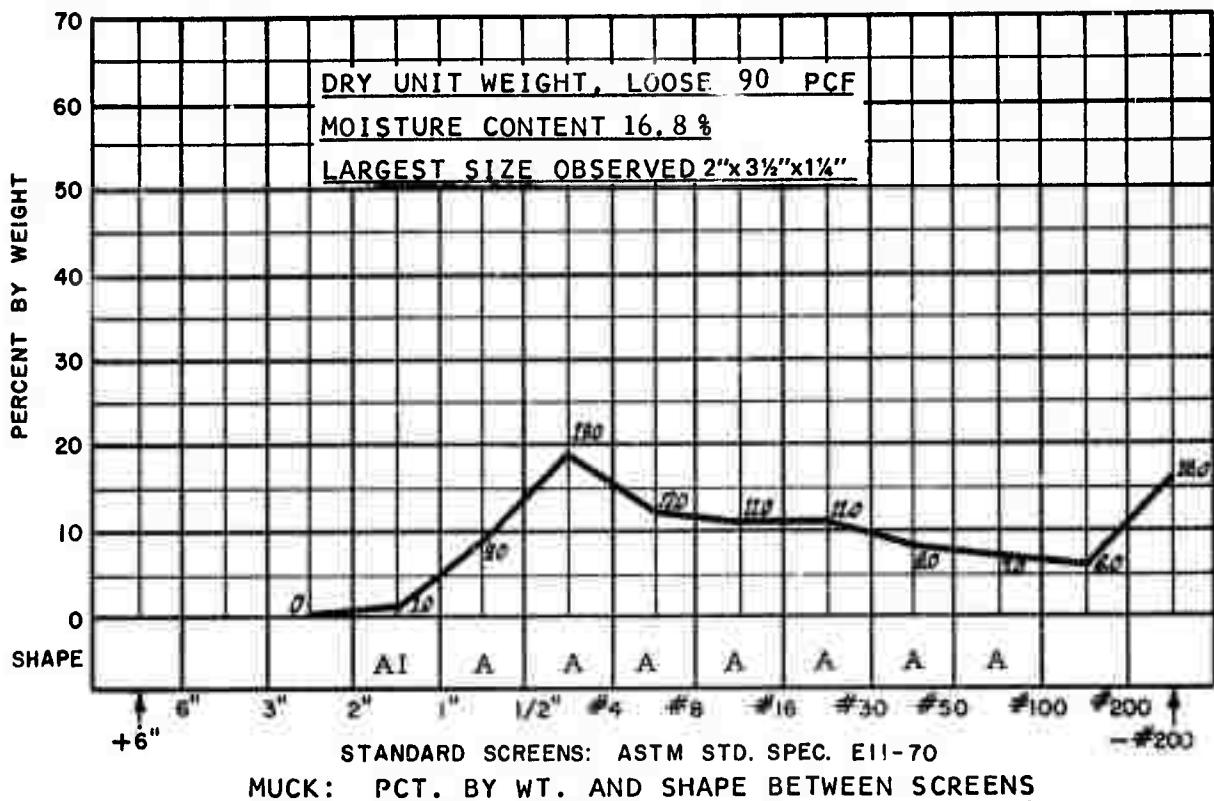
Abrasiveness Pot. Vol. Change, Material Spec. Gravity, Material
 N. A. Size (-)0.056" : 0 Size (-)0.75" : 2.53

ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 19.40 % Plastic Limit 18.16 % Shrinkage Limit 17.27 %
 Plasticity Index 1.24 % Toughness Index 0.31 % Flow Index 4.00 %

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop @ 3.7 % Moisture, 30°	Apparent Cohesion PSF @ 0.2 % Moisture, 0	Angle/Repose 10" Drop @ 3.7 % Moisture, 29°
Angle Slide Steel Plate @ 3.7 % Moisture, 32°	Bulk Density PCF @ 0.0 % Moisture, 101	Angle Internal Friction @ 0.2 % Moisture, 40°



SUMMARY

Rock Class: Igneous: Quartz monzonite, biotitic, fine to medium grained porphyry, frequent flat angled joints. Low strength (Est.). RQD (Est.) 86%. DUW: 137 PCF. Ground water: Dry. Hardness: NA.

System Class: RBM, Robbins H81R, 4' dia. 11 Robbins disc cutters. 6 RPM, 260 K ft # torque, 207 K # pull (average). Mucking and Haulage: Scooptram underground, rail skip to surface. Support: None.

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SYSTEM DATA SHEET
MDN

Ident. No. LK-6
Sheet 2

ROCK DATA:

Lithology: Igneous, quartz monzonite porphyry, intensely altered, coarse grained.
Uniaxial Compressive Strength: 7 KPSI.
RQD: (Estimated) 35%.
Dry Unit Weight: 158 PCF
Ground Water: None
Hardness: N.A.

TUNNEL DATA:

Size: 15' wide x 14' high, arched back. Grade: (-) 26%.
Ventilation System: 22 KCFM, pressure, 48" pipe and tubing, 150 HP @ 650'.
Utility System: 6" air, 2" water, 4" pump line.
Water Inflow: Minor
Power System: 4160/220, 110V lighting.
Haulage System: Wagner ST-8 Scooptram to surge pile at shaft station/rail mounted skip to surface. Personnel and supplies by Diesel truck.
Support System: 13 1/2" x 9' roof plates, 6' x 3/4" rock bolts at 4'.

EXCAVATION DATA:

Conventional Trackless System.
Drilling: Three boom hydrojib jumbo, w/PR123 drifters on 12' feeds.
Drill Round: 42 holes, 1 3/4" diameter, including 6 hole burn cut, and 1-4" diameter center hole, all 10 1/2' deep.
Explosives: 25#-1 1/2" x 8", 60% as primers, 25#-7/8" x 16", 30% in trim holes, 300#-1 1/2" x 16" in remainder of round. Powder factor: 4.7#/CY.
Blasting: Electrical, regular delays 0 through 15.
Mucking System: Scooptram
Guidance: Laser.

MUCK DATA

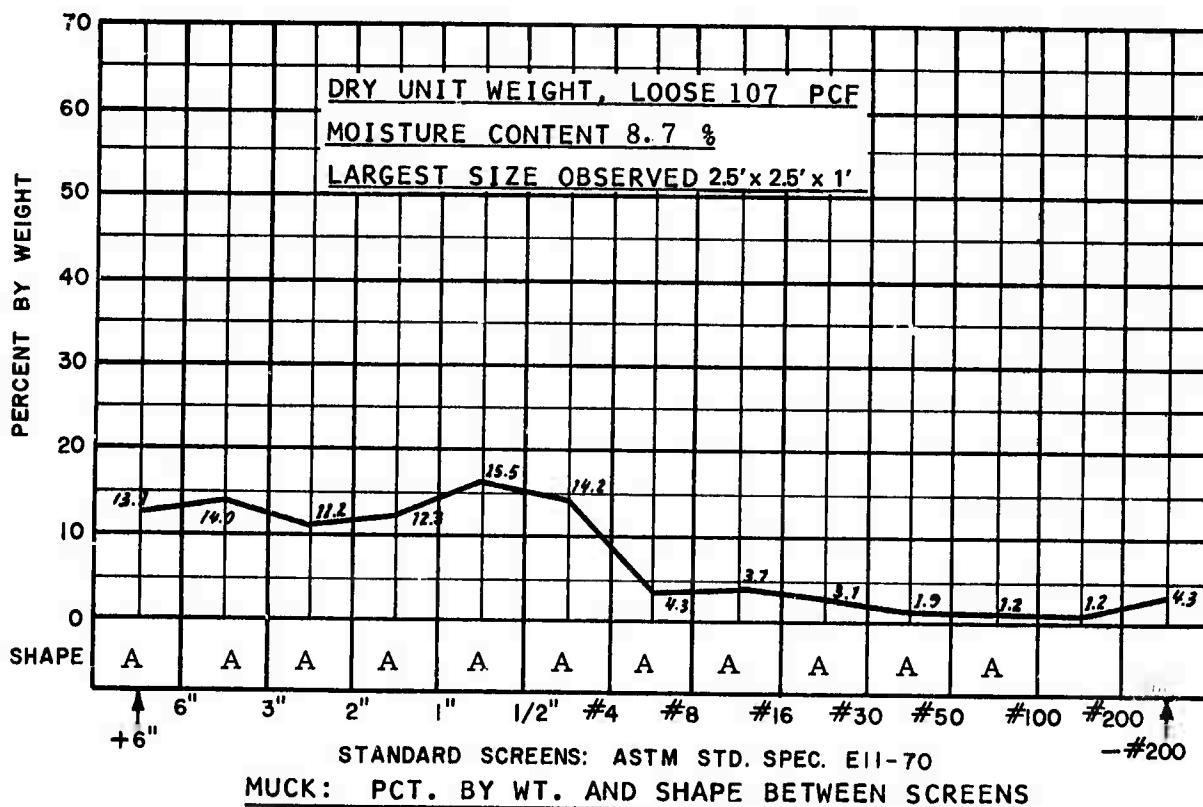
Abrasiveness N. A. Pot. Vol. Change, Material Size (-) 0.056" : 0 Spec. Gravity, Material Size (-) 0.75" : 2.68

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 18.00% Plastic Limit 17.12 % Shrinkage Limit 17.04 %
Plasticity Index 0.88 % Toughness Index 0.18 % Flow Index 5.00 %

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop @ 1.7 % Moisture, 29°	Apparent Cohesion PSF @ 0.2 % Moisture, 70	Angle/Repose 10" Drop @ 1.7 % Moisture, 26°
Angle Slide Steel Plate @ 1.7 % Moisture, 28°	Bulk Density PCF @ 0.0 % Moisture, 114	Angle Internal Friction @ 0.2 % Moisture, 45°



SUMMARY

Rock Class: Igneous: Quartz monzonite porphyry, intensely altered, course grained. Low strength. RQD (Est.) 85%. DUW: 158 PCF. Ground water: None. Hardness: N.A.

System Class: Conventional Trackless, 15' wide x 14' arch. Three boom jumbo, 42-10 1/2' holes, burn cut. PF 4.7 #/CY. Scooptram mucking and haulage rail skip to surface. Support: Roof plates and rock bolts at 4'.

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SYSTEM DATA SHEET
MDN

Ident. No. LK-7
Sheet 2

ROCK DATA:

Lithology: Igneous, quartz monzonite, coarse grained with many sulfide veinlets, highly fractured, pronounced orthogonal faulting.
Uniaxial Compressive Strength: 19K.
RQD: (Estimated) 50%.
Dry Unit Weight: 165 PCF
Ground Water: Saturated below working levels.
Hardness: N.A.

TUNNEL DATA:

Size: 12' x 12' Grade: (+) 0.4%
Ventilation System: 14 KCFM, pressure, 24" diameter pipe, 60 HP @ 400' from airway.
Utility System: 2" water, 4" airline, 8" pump line.
Water Inflow: None upper levels, 20-200 gpm lower levels.
Power System: 2400/480/240/110.
Haulage System: Muck, supplies, personnel by railcars, 8 ton battery locomotives, 10 ton bottom dump devel. cars, 36" gage, 45# rail.
Support System: 10 1/2' x 12" x 12" wood posts, 12" H beam cap sets at 5' centers in normal ground.

EXCAVATION DATA:

Conventional Rail System.
Drilling: 3 boom hydrojib jumbo, CF79 drifters on 6' shells or D89 drifters on 6' chain feeds.
Drill Round: 52 holes, 1 5/8" diameter, including 2 hole wedge burn and 4 relievers, 5' depth.
Explosives: 100# Carbamite per round (Amogel in wet ground).
Blasting: #6 caps, 8' fuse, timed by order of connection to igniter cord.
(Primacord used in place of primer powder) Powder factor 3.8#/CY.
Mucking System: Eimco 40 loader.
Guidance: Transit survey.

MUCK DATA

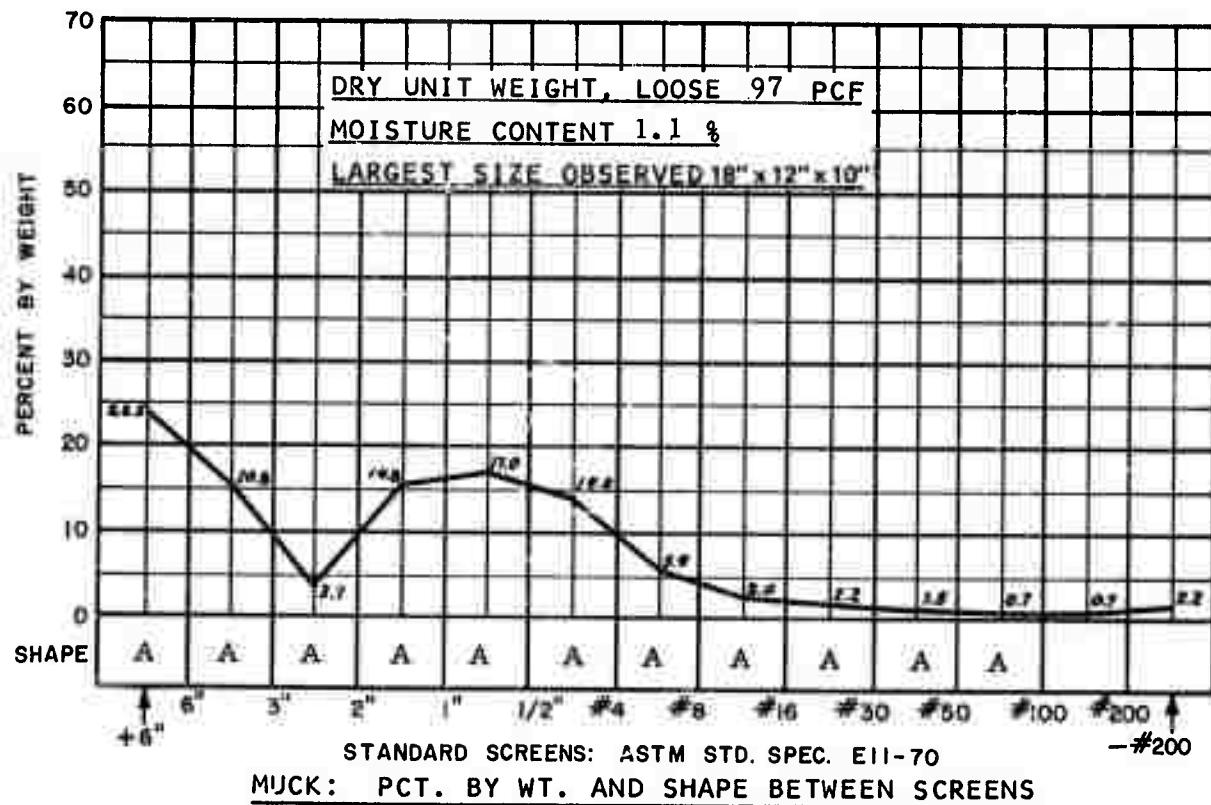
Abrasiveness Pot. Vol. Change, Material
 N. A. Size(-) 0.056" : 0 Spec. Gravity, Material
 Size(-) 0.75" : 2.72

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 12.50 % Plastic Limit 11.02 % Shrinkage Limit 10.52 %
 Plasticity Index 1.48 % Toughness Index 0.29 % Flow Index 5.1 %

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop @ 0.2 % Moisture, 36°	Apparent Cohesion PSF @ 0.2 % Moisture, 90	Angle/Repose 10" Drop @ 0.2 % Moisture, 31°
Angle Slide Steel Plate @ 0.2 % Moisture, 28°	Bulk Density PCF @ 0.0 % Moisture, 112	Angle Internal Friction @ 0.2 % Moisture, 44°



SUMMARY

Rock Class: Igneous: Quartz monzonite, coarse grained, many sulfide veinlets.
 Highly fractured, pronounced orthogonal faulting. High strength. RQD (Est.) 50%.
 DUW: 165 PCF. Ground water: Dry. Hardness: N.A.

System Class: Conventional Rail. 12' x 12'. Three boom jumbo, 52-5' holes, wedge cut. PF 3.8#/CY. Eimco 40 mucker. Haulage: Rail. Support: Wood posts and steel cap at 5'.

ROCK DATA:

Lithology: Metamorphic, granitic gneiss, highly metamorphosed, moderately to highly fractured, highly silicified.
Uniaxial Compressive Strength: 9 KPSI.
RQD: (Estimated) 10%.
Dry Unit Weight: 174 PCF.
Ground Water: Minimal-drains to other workings.
Hardness: NA

TUNNEL DATA:

Size: 13', round, Grade (+) 1/4 percent.
Ventilation System: 10 K CFM. exhaust, 24" pipe
Utility System: 4" air line, 2" water line.
Water Inflow: 5-10 gpm.
Power System: 4160/480V.
Haulage System: Personnel, muck, supplies by rail cars.
Support System: None.

EXCAVATION DATA:

Machine: Calweld, Hardrock model, #40.
Weight: 200 tons.
Cutters: 19-Smith Tool Tungsten Carbide Button, Gage: 6-GT-SH 8 roller.
Center: 1-TCB 24" tricone, interior: 12-GT-MH8 roller.
Rotation: Center cutter-26 RPM, Head-12 RPM.
Torque: 347 K # max.
Thrust: 1,128 K#. 677 K# operating
Muck Collection: Buckets from face, 24" conveyor to rear.
Power System: 480V Electro-Hydraulic, 825 HP.
Guidance System: Laser.

MUCK DATA

Abrasiveness
N. A.

Pot. Vol. Change, Material
Size : NA

Spec. Gravity, Material
Size : NA

ATTERBERG LIMITS, MATERIAL SIZE

IN.

Liquid Limit NA %
Plasticity Index NA %

Plastic Limit NA %
Toughness Index NA %

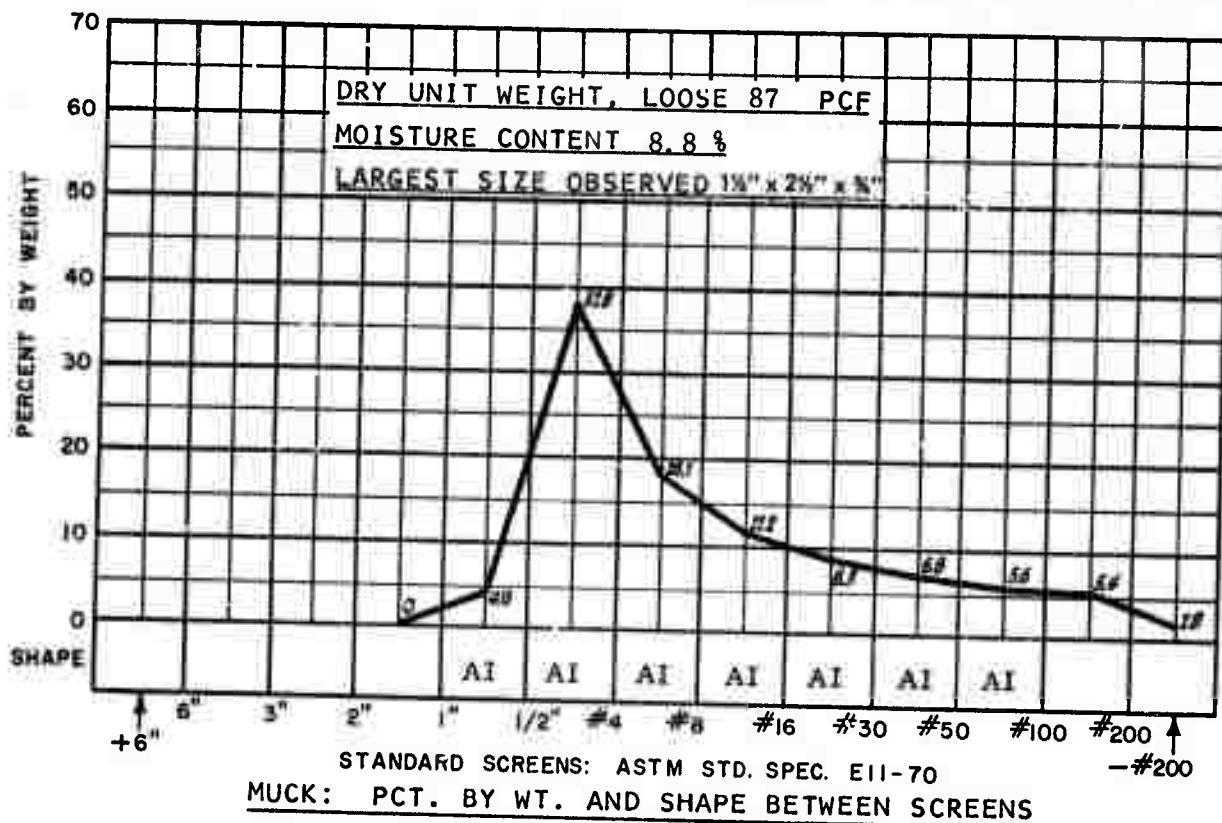
Shrinkage Limit NA %
Flow Index NA %

MATERIAL SIZE IN.

Angle/Repose 1" Drop
@ % Moisture, NA
Angle Slide Steel Plate
@ % Moisture, NA

Apparent Cohesion PSF
@ % Moisture, NA
Bulk Density PCF
@ % Moisture, NA

Angle/Repose 10" Drop
@ % Moisture, NA
Angle Internal Friction
@ % Moisture, NA



SUMMARY

Rock Class: Metamorphic: Granitic gneiss, highly metamorphosed and silicified, moderately to highly fractured. RQD: (Est.) 10%. DUW: 174 PCF. Medium strength. Ground water: Dry. Hardness: NA

System Class: TBM, Calweld #40, 13' dia. 19 Smith Tool TCB roller and tricone cutters. RPM: Head 12, center 26. 347K ft # torque, 677 K# thrust.

Mucking: Buckets to belt. Haulage: Rail. Support: None.

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SYSTEM DATA SHEET
MDN

Ident. No. CL-1
Sheet 2

ROCK DATA:

Lithology: Metamorphic, interlayered transition between quartzite and tactite. Moderately to strongly altered metasediments, with replacement pyrite, chalcopyrite and magnetite, and a high percentage of silicates, very fine to medium grained.

Uniaxial Compressive Strength: 26 KPSI.

RQD: (Estimated) 80%

Dry Unit Weight: 178 PCF.

Ground Water: None apparent

Hardness: NA

TUNNEL DATA:

Size: 16' wide x 14 1/2' high, arched back. Grade: (+) 2%.

Ventilation System: 52 KCFM, pressure in heading, 48" pipe and tubing.

Underground fans 48", 150 HP, 2 stage. Exhaust in return airway to 3-54", 150 HP, 2 stage surface fans.

Utility System: 6" compressed air, 2" water.

Water Inflow: None apparent.

Power System: 4160/220V for pumps and fans, 110V lighting.

Haulage System: Wagner ST-8 Scooptram to surge pile at shaft station/rail mounted skip to surface. Personnel and supplies by diesel truck.

Support System: 13 1/2" x 9' roof plates, 6' x 3/4" rock bolts at 4'.

EXCAVATION DATA:

Conventional Trackless System.

Drilling: Gardner-Denver 3 boom jumbo, 3 PR123 drifters, 12' feeds.

Drill Round: 42 holes, 1 3/4" diameter, including 6 hole burn cut, and 1 center hole, 4" diameter, all 6' deep.

Explosives: 15# - 1 1/2" x 8", 60% or 75% as primers, 15# - 7/8" x 16", 30% in trim holes, 25# - 1 1/2" x 16", 45% in 6 hole burn cut, 150# AN/FO in remainder of round. Powder factor 5#/cy.

Blasting: Electrical, regular delays, 0 through 15.

Mucking: Scooptram.

Guidance: Laser.

MUCK DATA

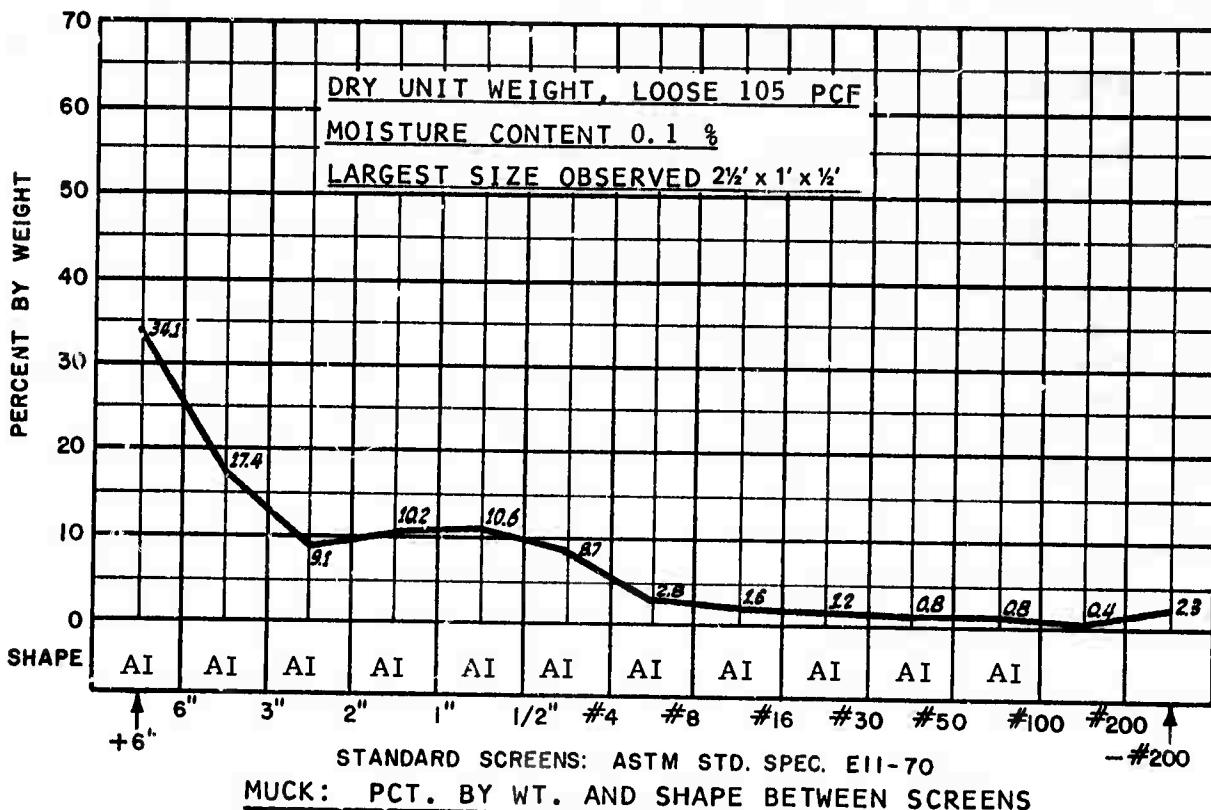
Abrasiveness N. A. Pot. Vol. Change, Material Size (-) 0.056": 0 Spec. Gravity, Material Size (-) 0.75": 3.21

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 18.25% Plastic Limit 17.92% Shrinkage Limit 17.80%
Plasticity Index 0.33% Toughness Index 0.06% Flow Index 5.50%

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop @ 1.5 % Moisture, 30°	Apparent Cohesion PSF @ 0.4 % Moisture, 175	Angle/Repose 10" Drop @ 1.5 % Moisture, 29°
Angle Slide Steel Plate @ 1.5 % Moisture, 29°	Bulk Density PCF @ 0.0 % Moisture, 117.8	Angle Internal Friction @ 0.4 % Moisture, 41°



SUMMARY

Rock Class: Metamorphic: Quartzite-tactite transition, very fine to medium grained, with replacement sulphides and magnetite, high in silicates. High strength. RQD:(Est.) 80%. DUW: 178 PCF. Ground water: Dry. Hardness: NA.
System Class: Conventional Trackless. 16' wide x 14-1/2' arch. Three boom jumbo, 42-6' holes, burn cut. PF 5#/CY. Scooptram mucking and haulage, rail skip to surface. Support: Roof plates and rock bolts at 4'.

ROCK DATA:

Lithology: Metamorphic, tactite, strongly altered calcareous metasediments, with replacement pyrite, chalcopyrite and magnetite, and a high percentage of silicates, fine to very fine grained.
Uniaxial Compressive Strength: 14 KPSI
RQD: (Estimated) 70%
Dry Unit Weight: 181 PCF
Ground Water: None apparent.
Hardness: NA

TUNNEL DATA:

Size: 15' wide x 14' high, arched back. Grade: (+) 2%.
Ventilation System: 50 KCFM, pressure in heading, 48" pipe and tubing.
Underground fans 48", 150 HP, 2 stage. Exhaust in return airway to 3-54", 150 HP, 2 stage surface fans.
Utility System: 6" compressed air, 2" water.
Water Inflow: None apparent.
Power System: 4160/220V for pumps and fans, 110V lighting.
Haulage System: Wagner ST-8 Scooptram to surge pile at shaft station/rail mounted skip to surface. Personnel and supplies by diesel truck.
Support System: 6" WF Steel Sets at 5'.

EXCAVATION DATA:

Conventional Trackless System:
Drilling: Gardner-Denver 3 boom jumbo, 3 PR123 drifters, 12' feeds.
Drill Round: 42 holes, 1 3/4" diameter, including 6 hole burn cut and 1 center hole, 4" diameter; all 6' deep.
Explosives: 15#-1 1/2" x 8", 60% or 75% as primers, 15#- 8" x 16" 30% in trim holes, 25#-1 1/2" x 16", 45% in 6 hole burn cut, 150# AN/F0 in remainder of round. Powder factor 5.5#/CY.
Blasting: Electrical, regular delays, 0 through 15
Mucking: Scooptram.
Guidance: Laser

MUCK DATA

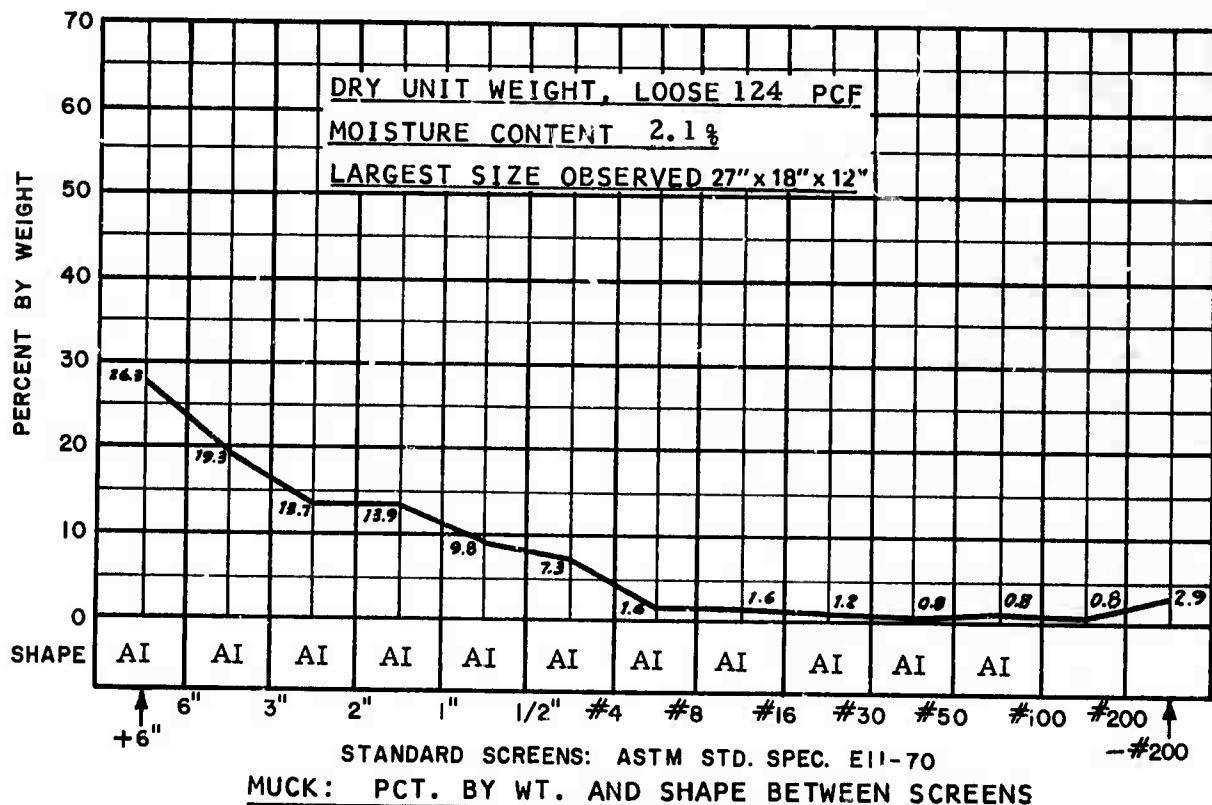
Abrasiveness Pot. Vol. Change, Material
 N. A. Size (-) 0.056" : 0 Spec. Gravity, Material
 Size (-) 0.75" : 3.36

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 19.00% Plastic Limit 17.95 % Shrinkage Limit 16.43 %
 Plasticity Index 1.05 % Toughness Index 0.19 % Flow Index 5.40 %

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop @ 2.0 % Moisture, 37°	Apparent Cohesion PSF @ 0.2 % Moisture, 165	Angle/Repose 10" Drop @ 2.0 % Moisture, 35°
Angle Slide Steel Plate @ 2.0 % Moisture, 30°	Bulk Density PCF @ 0.0 % Moisture, 115	Angle Internal Friction @ 0.2 % Moisture, 43°



SUMMARY

Rock Class: Metamorphic: Tactite, fine to very fine grained, with replacement sulphides and magnetite, high in silicates. Medium strength (Est.).
 RQD (Est.) 70%. DUW: 181 PCF. Ground water: Dry. Hardness: N.A.

System Class: Conventional Trackless. 15' wide x 14' arch. Three boom jumbo, 42-6' holes, burn cut. PF 5.5#/CY. Scooptram mucking and haulage, rail skip to surface. Support. Steel sets at 5'.

MDN STUDY
 9/1/72

SYSTEM DATA SHEET
 MDN

Ident. No. LK-4
 Sheet 2

ROCK DATA:

Lithology: Metamorphic, interlayered bands of hematite and martite, highly jointed, normally flat lying, but often highly folded. Natural iron over 60%, silica 5%.

Uniaxial Compressive Strength: 7 KPSI.

RQL: (Estimated) 10%

Dry Unit Weight: 207 PCF

Ground Water: Formation generally dry.

Hardness: NA

TUNNEL DATA:

9'-11 1/2" diameter; normal grade: 0%.

Ventilation System: 3 KCFM, pressure, 8" dia. tube, 5 HP @ 250' from main level.

Utilities: 2" air line, 1" water line, 2-1 1/2" pressure and 1-3" return hydraulic lines.

Water Inflow: None

Power System: 110V lighting, 440V to scraper hoist.

Muck Haulage: 30 HP hoist, and 42" scraper to raise, all rail on main level. Personnel, rail and ladders; supplies by rail cars and hoist.

Support: Continuous; 9'-6" dia. x 4" WF sets at 45".

EXCAVATION DATA:

Machine: Calweld Oscillator. Wt: 69 K#.

Cutters: 278 Carboloy drag bits. Gage: 20 rippers (experimental).

Interior: 258 "J" tools.

Rotation: 8 RPM

Torque: 1200 K ft. #.

Thrust: 300 K# max., 285 K# operating.

Anchorage: Thrust on installed sets, 285K# operating.

Muck Collection: Flight conveyor to rear of machine, removal by scraper.

Power System: Remote power unit; 2-90 gpm, 2500 psi hydraulic pumps and 125 HP motors on main level; thrust and rotation through hydraulic cylinders.

Guidance System: Survey.

MUCK DATA

Abrasiveness
N. A.

Pot. Vol. Change, Material
Size (-) 0.056": 0

Spec. Gravity, Material
Size (-) 0.75": 4.34

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 17.8 %
Plasticity Index 2.7 %

Plastic Limit 15.1 %
Toughness Index 0.66 %

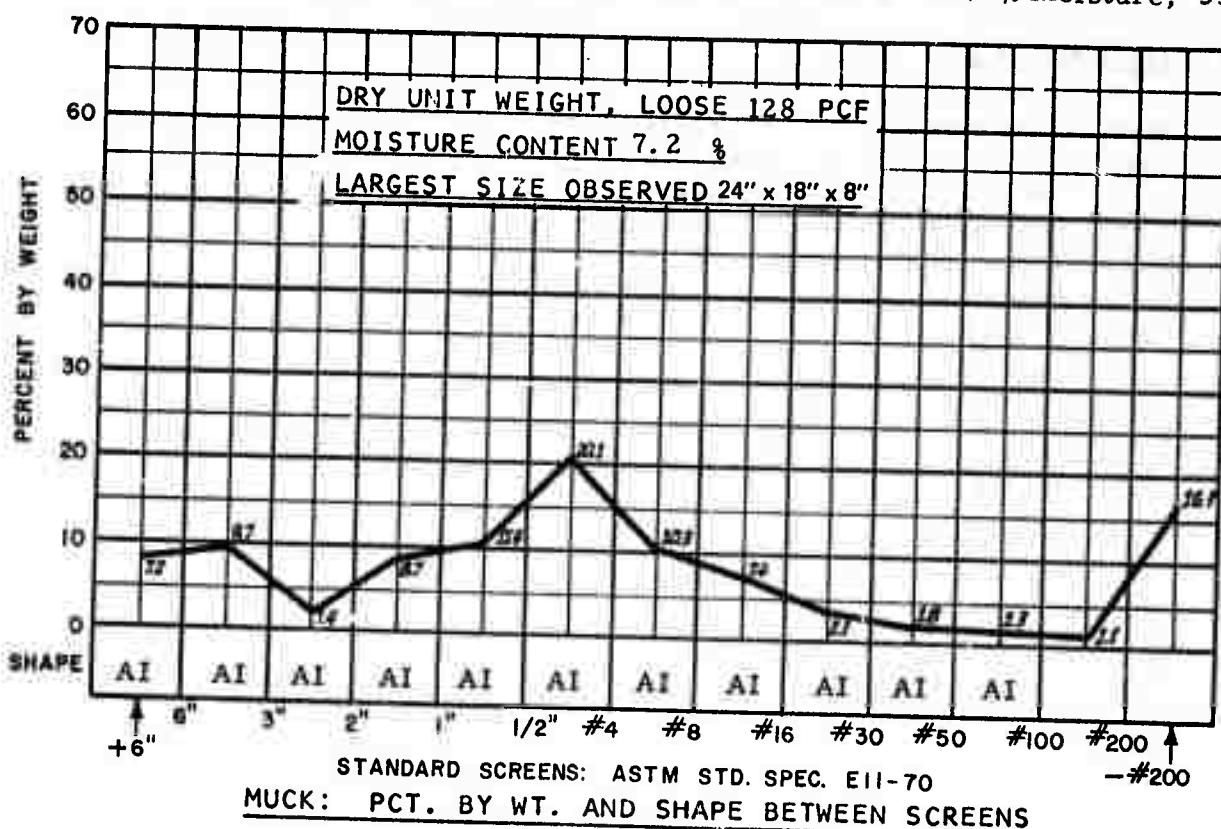
Shrinkage Limit 13.9 %
Flow Index 4.1 %

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop
@ 6.2 % Moisture, 37°
Angle Slide Steel Plate
@ 6.2 % Moisture, 31°

Apparent Cohesion PSF
@ 6.9 % Moisture, 235
Bulk Density PCF
@ 0.0 % Moisture, 141

Angle/Repose 10" Drop
@ 6.2 % Moisture, 35°
Angle Internal Friction
@ 6.9 % Moisture, 35°



SUMMARY

Rock Class: Metamorphic; Hematite and martite interlayered, highly jointed, bedding normally flat, often highly folded. Low strength. RQD (Est.) 10%. DUW: 207 PCF. Ground water: Dry. Hardness: NA.

System Class: TBM, oscillator, Calweld #53, 9'11 1/2" dia. 278 Carboloy drag bits. 8 RPM, 1200 K ft # torque, 285 K# thrust. Mucking: Flight conveyor and scraper to raise. Haulage: Rail. Support: Continuous, 9'6" dia. x 4" H sets at 45".

MDN STUDY

9/1/72

SYSTEM DATA SHEET

MDN

Ident. No. MB-1

Sheet 2

ROCK DATA:

Lithology: Metamorphic, interlayered hematite and martite, highly jointed, normally flat lying, often highly folded. Natural iron over 60%, silica 5%.
Uniaxial Compressive Strength: NA PSI
RQD: (Estimated) 10%.
Dry Unit Weight: NA
Ground Water: None
Hardness: NA

TUNNEL DATA:

Size: 10' wide x 9'-6" (7' cap and 8' post). Grade: Level
Ventilation System: 4 KCFM pressure, 8" diameter pipe and tubing, 15 HP @ 600', and 8" exhaust, 5 HP @ 100'.
Utility System: 2" airline, 1" water line
Water Inflow: None
Power System: 2300/440V.
Haulage System Muck, 30 HP hoist and 48" scraper from surge pile at rear of miner to chute - 160 CF cars, 30 ton tandem locomotives on 30" gage 60# rail to shaft pocket, 14 ton skips to surface.
Support System: 8"-58# WF sets, 7' cap, 8' post, at 4'-5", wood lagging and pipe spiling, 8-1" diameter or 6-2" diameter in back.

EXCAVATION DATA:

Machine: Alpine, Model F-6A Total Weight: 11 tons.
Cutters: 68 Kennametal 43 KH carbide tipped "plumb bob" type, mounted on twin ripper heads at 90° to boom.
Rotation: 60 RPM about horizontal axis; boom moved vertically and horizontally by hydraulic cylinders.
Torque: 49.6 HP.
Thrust: Sumping thrust from 2-10 HP crawler motors.
Anchor Pressure: Crawlers only.
Muck Collection: Central 14" flight conveyor fed by two gathering arms on inclined apron, discharging to surge pile.
Power System: 440V.
Guidance: Transit lines.

MUCK DATA Test Data NA.

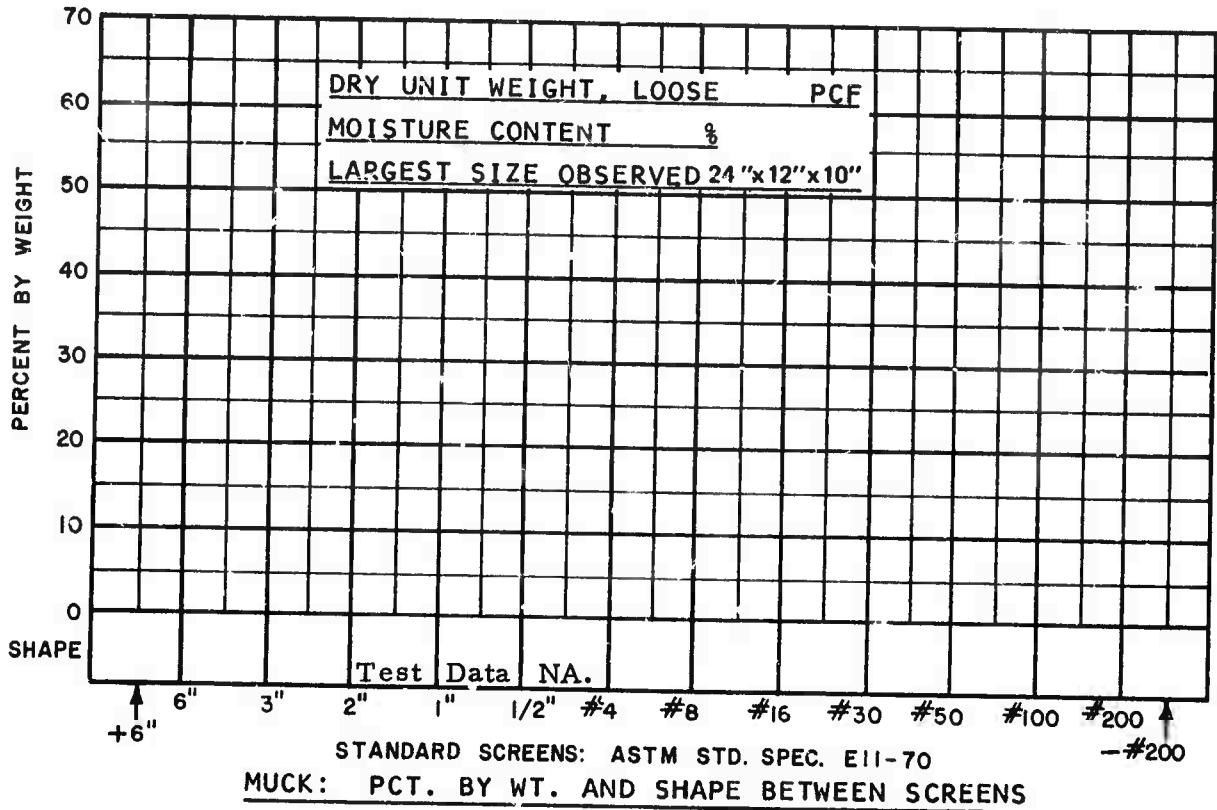
Abrasiveness Pot. Vol. Change, Material
N. A. Size : Spec. Gravity, Material
 Size : IN.

ATTERBERG LIMITS, MATERIAL SIZE

Liquid Limit	%	Plastic Limit	%	Shrinkage Limit	%
Plasticity Index	%	Toughness Index	%	Flow Index	%

MATERIAL SIZE IN.

Angle/Repose 1" Drop @ % Moisture,	Apparent Cohesion PSF @ % Moisture,	Angle/Repose 10" Drop @ % Moisture,
Angle Slide Steel Plate @ % Moisture,	Bulk Density PCF @ % Moisture,	Angle Internal Friction @ % Moisture,



SUMMARY

Rock Class: Metamorphic: Hematite and martite interlayered, highly jointed, bedding normally flat, often highly folded. Low strength. RQD (Est.) 10%.
DUW: NA. Ground water: Dry. Hardness: NA.

System Class: TBM, Twin head, Alpine F-6A, 10' wide x 9'6" heading.
68 Kenna.metal T.C. tipped bits. 60 RPM, 49.6 HP head torque, 20 HP sumping thrust. Mucking: Gathering arms, flight conveyor. Haulage: Scraper to rail cars to skip. Support: Steel sets, pipe spiles.

MDN STUDY

9/1/72

SYSTEM DATA SHEET

MDN

Ident. No. MB-3

Sheet 2

ROCK DATA:

Lithology: Metamorphic, argillaceous quartzite, medium to thin bedded, moderately to highly folded. Beds high angled to vertical, moderate fracturing sub-parallel to beds and vertical across beds.

Uniaxial Compressive Strength: NA KPSI

RQD: 75% (Estimated for vertical hole).

Dry Unit Weight: NA PCF

Ground Water: None

Hardness: NA

TUNNEL DATA:

Size: 9' W x 10.7', 1 1/2' R. top corner arch. Grade: +1/2%

Ventilation System: 7 KCFM pressure, 24" pipe and tubing, 40 HP at 800'.

Utility System: 4" air line, 2" water line.

Water Inflow: None to minor.

Power System: 2300/480/120 (lighting).

Haulage System: Muck, personnel, supplies by rail cars, 24" gage, 40# rail, 6 ton battery locomotive, 60 CF side dump cars.

Support System: 9' x 13" mats, parallel to centerline, 2 in top and 2 each rib, 4 3/4" x 6' rock bolts per mat.

EXCAVATION DATA:

Conventional Rail System.

Drilling: 3 boom jumbo, 2-S83F and 1-D99 machines, 8' screw feeds.

Drill Round: 44 holes: 2-4" and 42-1 5/8" diameter, burn cut, 7' depth.

Explosives: 100# Nitite, 25#-60 WR 1" x 16" primers.

Blasting: Electrical, zero and 14 regular delays. Powder Factor: 5.4#/CY.

Mucking System: Atlas-Copco LM56 overhead.

Guidance: Transit lines.

MUCK DATA Test Data NA.

Abrasiveness Pot. Vol. Change, Material
N. A. Size : Spec. Gravity, Material
Size :

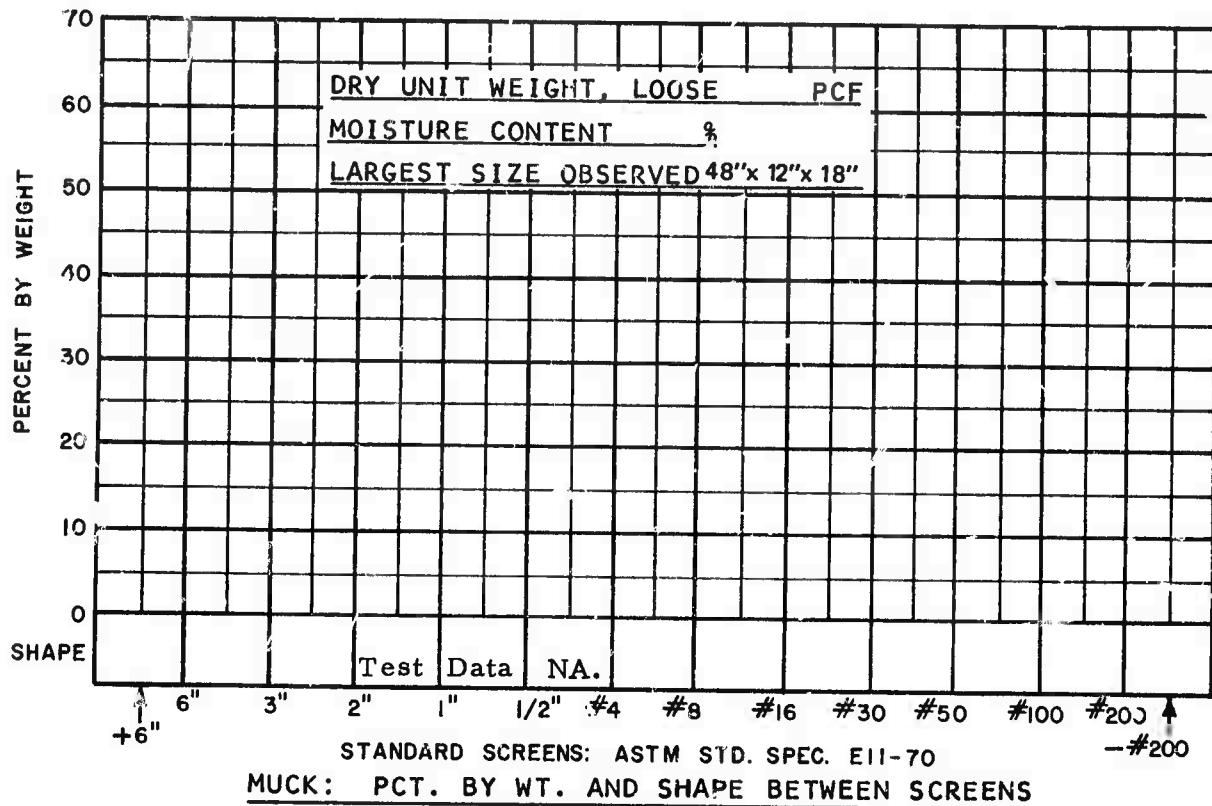
ATTERBERG LIMITS, MATERIAL SIZE

IN.

Liquid Limit	%	Plastic Limit	%	Shrinkage Limit	%
Plasticity Index	%	Toughness Index	%	Flow Index	%

MATERIAL SIZE IN.

Angle/Repose 1" Drop @ % Moisture,	Apparent Cohesion PSF @ % Moisture,	Angle/Repose 10" Drop @ % Moisture,
Angle Slide Steel Plate @ % Moisture,	Bulk Density PCF @ % Moisture,	Angle Internal Friction @ % Moisture,



SUMMARY

Rock Class: Metamorphic: Argillaceous quartzite, moderately fractured, moderately to highly folded, medium to thin bedded. Strength: NA.
RQD (Est.) 75%. DUW: NA. Ground water: None. Hardness: NA.

System Class: Conventional Rail: 9' x 10'7", 3 boom jumbo, 44-7' holes, burn cut. PF 5.4#/CY. Mucking: Atlas Copco LM56. Haulage: Rail. Support: Rock bolts and mats.

MDN STUDY
9/1/72

SYSTEM DATA SHEET
MDN

Ident. No. ST-1
Sheet 2

ROCK DATA:

Lithology: Metamorphic, quartzite, with minor filled veinlets, thin bedded to massive, moderately folded, moderately to highly fractured/jointed, beds dip 75°-90°.

Uniaxial Compressive Strength: NA

RQD: (Estimated) Vertical: 50%, horizontal 20-30%.

Dry Unit Weight: NA

Ground Water: Minor

Hardness: NA

TUNNEL DATA:

Size: 10' x 10' with 1 1/2' top corner radius. Grade: (+) 0.5%.

Ventilation: 13.5 KCFM, pressure, 24" diameter pipe, 80 F.P @ 1700' from cooling unit.

Utility System: 4" air line, 2" water line, 2" pumpline.

Power System: 2300/480/120.

Haulage System: Muck, Eimco 912B-LHD to skip pocket, skips and rail to surface.

Personnel, Supplies: Rail, cage to level, LHD or Jumbo on level.

Support System: 13" x 9' plates, 5' x 5/8" rock bolts at 3 1/2', plates and rock bolts on ribs where needed.

EXCAVATION DATA:

Conventional Trackless System.

Drilling: 2 boom hydrojib jumbo, 8' feed, D-93 drifters.

Drill Round: 48 holes, 1 5/8" diameter x 8' V cut.

Explosives: 265#, 250# Nilite, 15# Trojan 60 WR. Powder factor, 9.5#/CY.

Blasting: Electrical, Dupont Acudet 0-14 delay caps.

Mucking: Eimco 912B-LHD.

Guidance: Laser

MUCK DATA Test Data NA.

Abrasiveness N. A.	Pot. Vol. Change, Material Size :	Spec. Gravity, Material Size :
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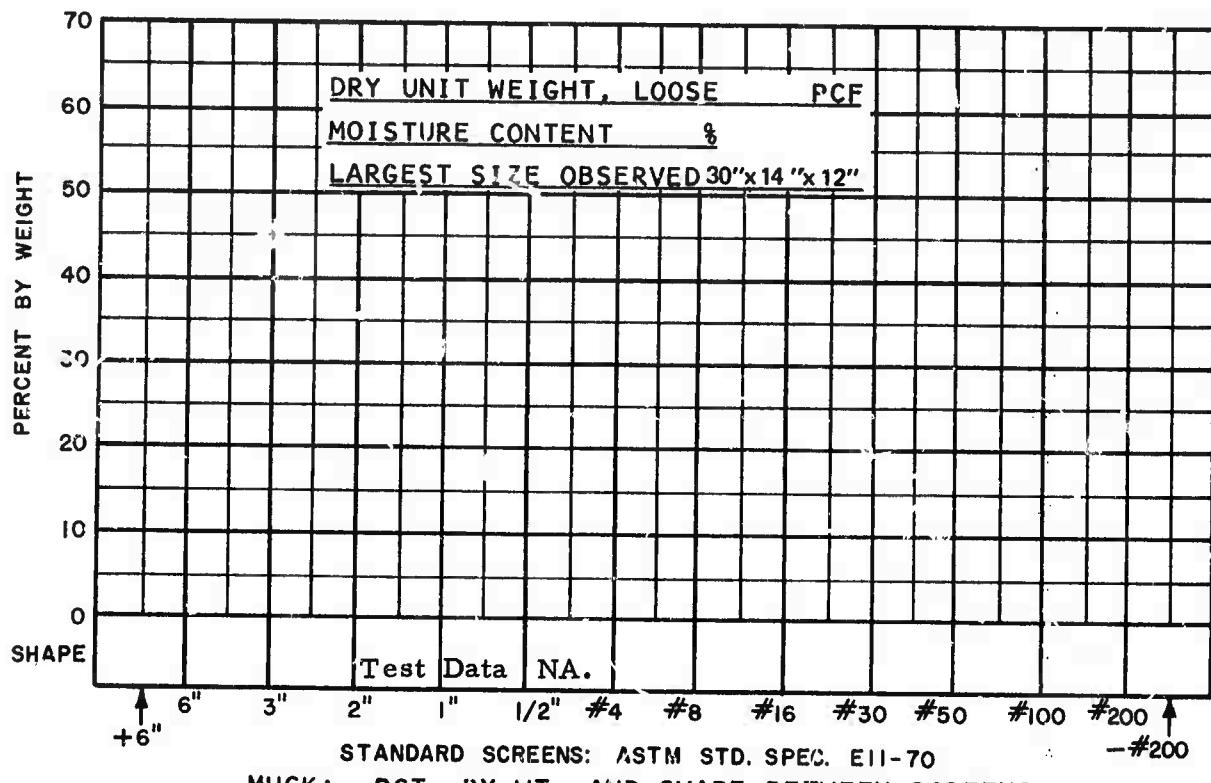
ATTERBERG LIMITS, MATERIAL SIZE

IN.

Liquid Limit %	Plastic Limit %	Shrinkage Limit %
Plasticity Index %	Toughness Index %	Flow Index %

MATERIAL SIZE IN.

Angle/Repose 1" Drop @ % Moisture,	Apparent Cohesion PSF @ % Moisture,	Angle/Repose 10" Drop @ % Moisture,
Angle Slide Steel Plate @ % Moisture,	Bulk Density PCF @ % Moisture,	Angle Internal Friction @ % Moisture,



SUMMARY

Rock Class: Metamorphic: Quartzite minor filled veinlets, moderately to highly fractured/jointed, moderately folded, beds dip 75° to 90°. Strength: NA. RQD (Est.) 50%. DUW: NA. Hardness: NA.

System Class: Conventional Trackless: 10' x 10', 2 boom jumbo, 48-8' holes, V cut. PF 9.5#/CY. Mucking: Eimco 912B. Haulage: LHD. Support: Rock bolts and plates.

MDN STUDY

9/1/72

SYSTEM DATA SHEET

MDN

Ident. No. CR-1

Sheet 2

ROCK DATA:

Lithology: Metamorphic, phyllite, with vein quartz and chlorite schist, highly metamorphosed and folded, with minor faulting.

Uniaxial Compressive Strength: 19 KPSI

RQD: (Estimated) 70%

Dry Unit Weight: 187 PCF

Ground Water: Dry

Hardness: NA

TUNNEL DATA:

Size: 7'-6" wide x 8'-6" arch.

Ventilation: 7 KCFM, 16" diameter pipe, 30 HP @ 300'. Fan integral with mechanical cooling unit.

Utility System: 2" water line, 2" airline, 4" water line to cooling unit.

Water Inflow: Minor

Power System: 2400/440/110V.

Haulage System: Muck, supplies, personnel by railcars, 6 and 8 ton locomotives 1 1/2 ton rocker dump cars, 18" gage, 40# rail car passes 80'-300' from face.

Support System: Normally none, 5/8" x 6' rock bolts as required.

EXCAVATION DATA:

Conventional Rail System

Drilling: 2-6' feed air legs, mounting 3" jackhammers.

Drill Round: 34 holes, 5-2" diameter burncut, circular or box relievers 29 x 1 1/4", average advance 10' per round.

Explosives: 140#, 131# AN/FO, 9#-1 x 6", 60% primers.

Blasting: Electrical, 7 millisecond delays, 10 regular delays.

Powder factor, 7.0#/CY.

Mucking: Eimco, model 21.

Guidance: Transit survey.

MUCK DATA

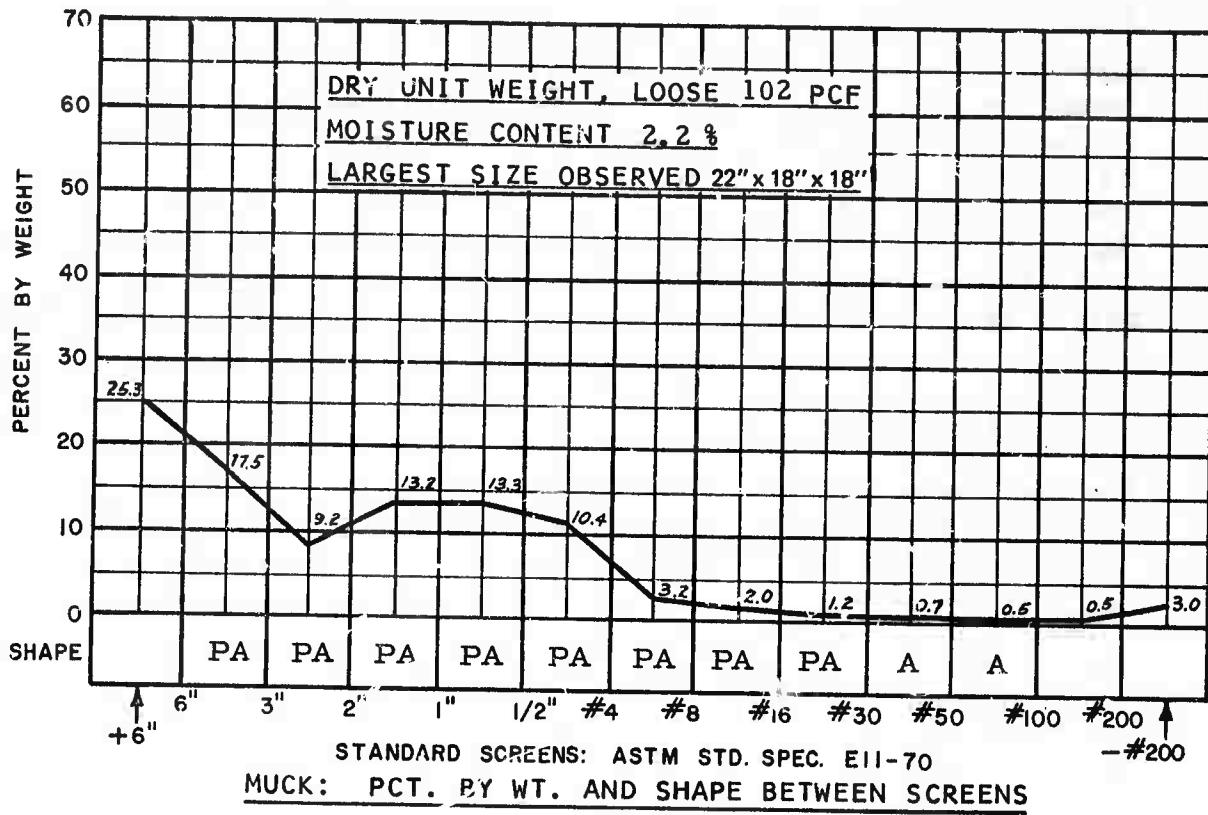
Abrasiveness N. A. Pot. Vol. Change, Material Size (-)0.056": 0 Spec. Gravity, Material Size (-)0.75": 2.84

ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 18.80% Plastic Limit 16.06 % Shrinkage Limit 15.12 %
Plasticity Index 2.74 % Toughness Index 1.01 % Flow Index 2.70 %

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop @ 3.1 % Moisture, 40°	Apparent Cohesion PSF @ 2.0 % Moisture, 160	Angle/Repose 10" Drop @ 3.1 % Moisture, 34°
Angle Slide Steel Plate @ 3.1 % Moisture, 31°	Bulk Density PCF @ 0.0 % Moisture, 99	Angle Internal Friction @ 2.0 % Moisture, 39°



SUMMARY

Rock Class: Metamorphic: Phyllite with vein quartz and chlorite schist, highly metamorphosed and folded. High strength. RQD (Est.) 70%. DUW: 187 PCF. Ground water: Dry. Hardness: NA.

System Class: Conventional Rail. 7' 6" wide x 8' 6" arch, two air leg drills, 34-10' holes, burn cut. PF 7.0 # /CY. Mucking: Eimco 21. Haulage: Rail. Support: None.

MDN STUDY
9/1/72

SYSTEM DATA SHEET
MDN

Ident. No. HS-1
Sheet 2

ROCK DATA:

Lithology: Metamorphic, mica schist, occasional quartz laminations.
Uniaxial Compressive Strength: NA
RQD: (Estimated) 80%.
Dry Unit Weight: NA
Ground Water: Dry
Hardness: NA

TUNNEL DATA:

Size: 11'-6" diameter. Grade: (-) 0.03%.
Ventilation: 3.6 KCFM, exhaust, @ 3475', 20" diameter pipe, 40 HP.
Utility System: 4" airline, 4" waterline, 6" pumpline.
Water Inflow: 40 GPM
Power System: 6600V/440V.
Haulage System: Muck, supplies, personnel by railcars, 10 ton locomotive
17 CY cars, 36" gage, 70# rail.
Support System: Half circle bolted steel lagging in fault zones, pinned to ribs.

EXCAVATION DATA:

Machine: Jarva, 12-1100, Total Weight: NA.
Cutters: 30 Reed steel disc and 6 Jarva TCB disc. Cage: 6 TCB QKC-3W.
2 disc. Interior: 28 steel 3 disc QK3. Center: 2 steel 5 disc QK-1.
Rotation: NA RPM.
Torque: NA.
Thrust: NA.
Muck Collection: Buckets from face, belt to rear.
Power System: NA.
Guidance: Laser.

MUCK DATA

Abrasiveness
N. A.

Pot. Vol. Change, Material
Size : NA

Spec. Gravity, Material
Size : NA

ATTERBERG LIMITS, MATERIAL SIZE

IN.

Liquid Limit NA %
Plasticity Index NA %

Plastic Limit NA %
Toughness Index NA %

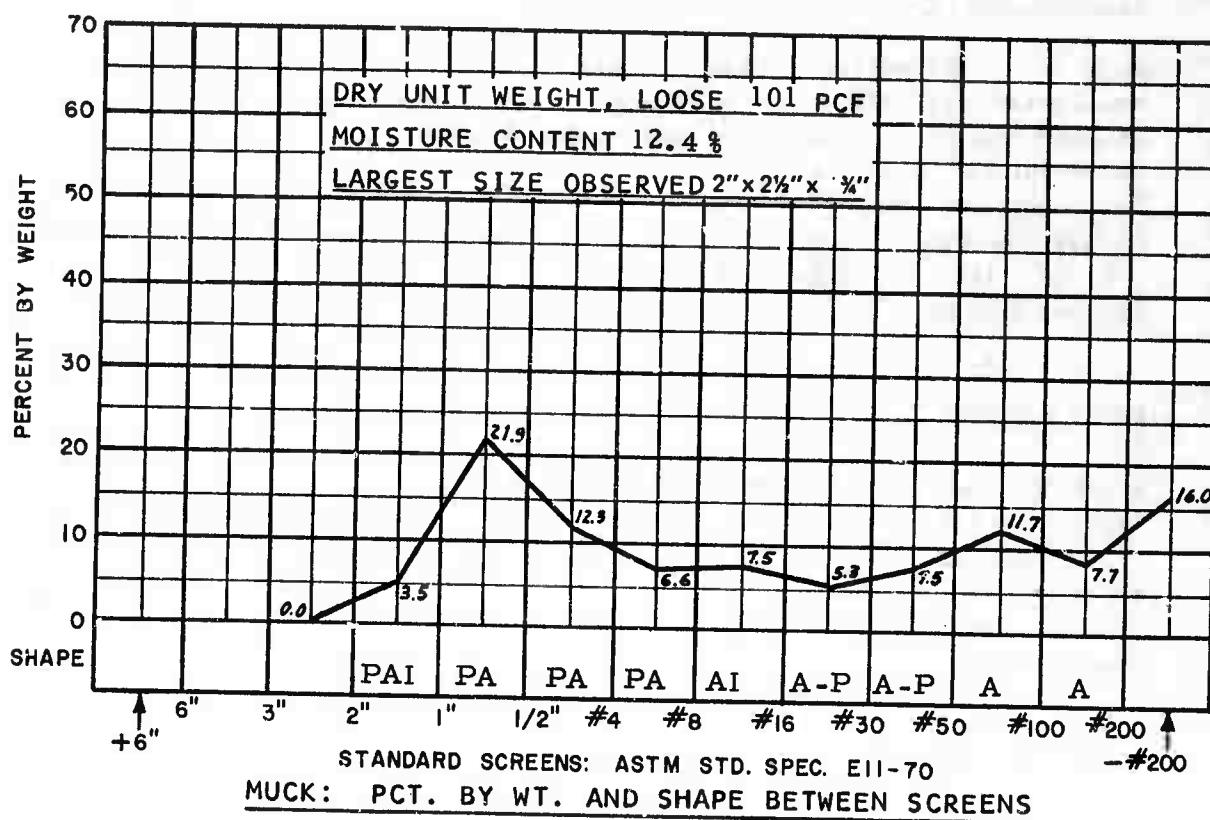
Shrinkage Limit NA %
Flow Index NA %

MATERIAL SIZE IN.

Angle/Repose 1" Drop
@ % Moisture, NA
Angle Slide Steel Plate
@ % Moisture, NA

Apparent Cohesion PSF
@ % Moisture, NA
Bulk Density PCF
@ % Moisture, NA

Angle/Repose 10" Drop
@ % Moisture, NA
Angle Internal Friction
@ % Moisture, NA



SUMMARY

Rock Class: Metamorphic: Mica schist, occasional quartz lamination.

Strength: NA. RQD (Est.) 80%. DUW: NA. Ground water: Dry.

Hardness: NA.

System Class: TBM, Jarva 12-1100, 11'6" dia. 30 Reed and 6 Jarva discs. RPM: NA, Torque: NA, Thrust: NA. Mucking: Buckets to belt. Support: None.

MDN STUDY
9/1/72

SYSTEM DATA SHEET
MDN

Ident. No. NY-1
Sheet 2

ROCK DATA:

Lithology: Metamorphic, mica schist, occasional quartz laminations.
Uniaxial Compressive Strength: NA.
RQD: (Estimated) 90%.
Dry Unit Weight: NA.
Ground Water: Dry
Hardness: NA.

TUNNEL DATA:

Size: 8'-6" diameter. Grade: (+) 0.03%.
Ventilation: 18 KCFM, exhaust @ 1500', 12" diameter pipe, 40 HP
Utility System: 4" airline, 4" waterline, 4" pumpline.
Water Inflow: 20 GPM.
Power System: 6600/440V.
Haulage System: Muck, supplies, personnel by railcars 10 ton locomotive
13 CY cars, 36" gage, 70# rail.
Support System: Half circle bolted steel lagging in fault zones, pinned to ribs.

EXCAVATION DATA:

Machine: Jarva 8-806. Total Weight: NA.
Cutters: 14 Reed disc and 3 Jarva TCB disc. Gage 3 TCB disc QKC-3W
Interior, 12 TCB disc QC-3, center 2 steel tooth type.
Rotation: NA RPM.
Torque: NA.
Thrust: NA.
Muck Collection: Buckets from face, belt to rear.
Power System: NA.
Guidance: Laser.

MUCK DATA

Abrasiveness
N. A.

Pot. Vol. Change, Material
Size : NA

Spec. Gravity, Material
Size : NA

ATTERBERG LIMITS, MATERIAL SIZE

IN.

Liquid Limit NA %

Plastic Limit NA %

Shrinkage Limit NA %

Plasticity Index NA %

Toughness Index NA %

Flow Index NA %

MATERIAL SIZE IN.

Angle/Repose 1" Drop
@ % Moisture, NA

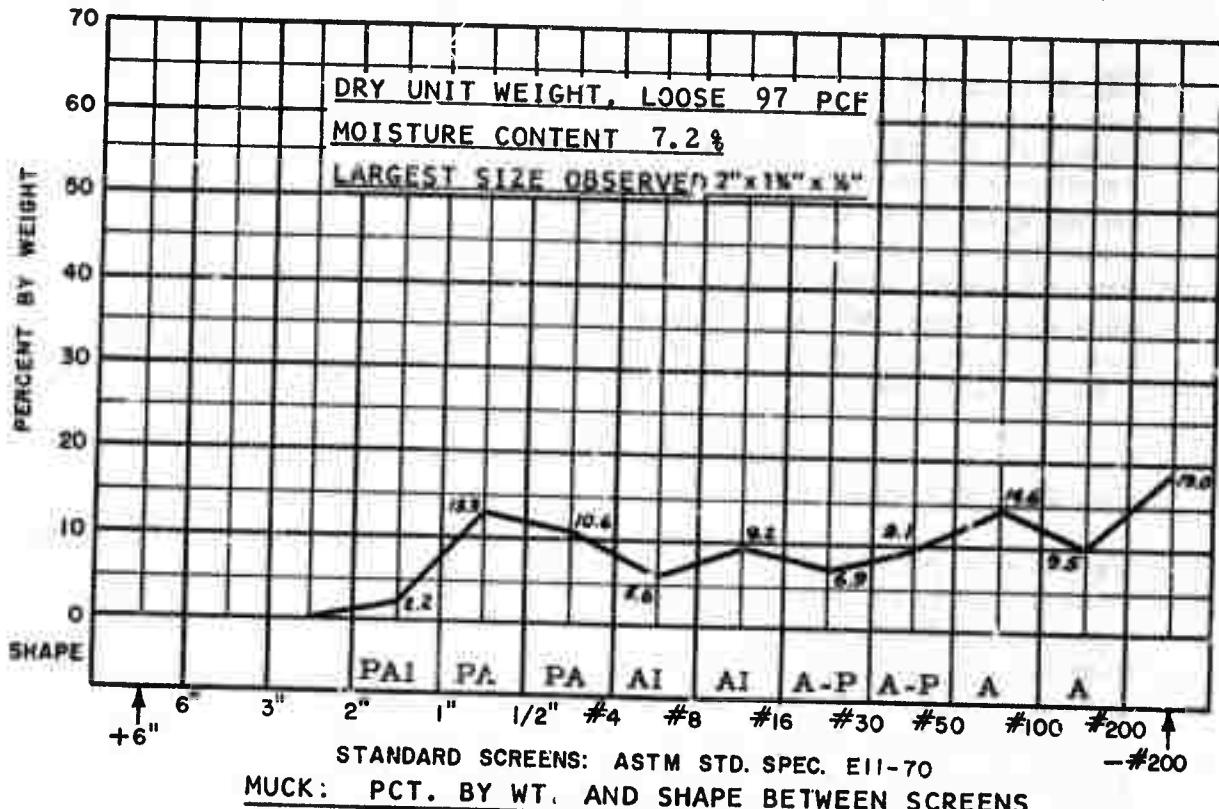
Apparent Cohesion PSF
@ % Moisture, NA

Angle/Repose 10" Drop
@ % Moisture, NA

Angle Slide Steel Plate
@ % Moisture, NA

Bulk Density PCF
@ % Moisture, NA

Angle Internal Friction
@ % Moisture, NA



SUMMARY

Rock Class: Metamorphic: Mica schist, occasional quartz laminations.

Strength: NA. RQD (Est.) 90%. D₁₀: NA. Ground water: Dry.

Hardness: NA.

System Class: TBM, Jarva 8-806, 8'6" dia. 14 Reed and 3 Jarva discs and rollers. RPM: NA. Torque: NA. Thrust: NA. Mucking: Buckets to belt. Haulage: Rail. Support: None.

MDN STUDY
9/1/72

SYSTEM DATA SHEET
MDN

Ident. No. NY-2
Sheet 2

ROCK DATA:

Lithology: Metamorphic, gray mica schist, occasional quartz seams, mica varies from dense fine grained to extremely coarse.
Uniaxial Compressive Strength: 11 KPSI.
RQD: (Estimated) 30%
Dry Unit Weight: 165 PCF
Ground Water: Major inflow occurs in faults and fault zones.
Hardness: NA

TUNNEL DATA:

Size: 11', diameter. Grade: (+) 1 to 3%
Ventilation System: 4 KCFM exhaust 14" pipe.
Utility System: 4" waterpipe, no airline.
Water Inflow: 60 gpm, drains in ditch
Power System: 4160/480V
Haulage System: Muck, personnel, supplies by rail cars.
Support System: None, occasional semi-circular plates pinned at spring line in fault zones

EXCAVATION DATA:

Machine: Jarva, Mark 11-1100, Total Weight: 70 tons
Cutters: 34 Reed, type QK steel multiple disc. Gage: 6 triple disc.
Center: 2-triple disc. Interior: 26 triple disc.
Rotation: Cutterhead, 10.75 RPM
Torque: 244 K ft. #
Anchor Pressure: Maximum 3,402 K#.
Thrust: 1,134 K#. operating
Muck System: Buckets from face, belt to rear.
Power System: Four 125 HP, 480V motors drive head, 40 HP 480V motor drive hydraulic system.
Guidance System: Laser

MUCK DATA

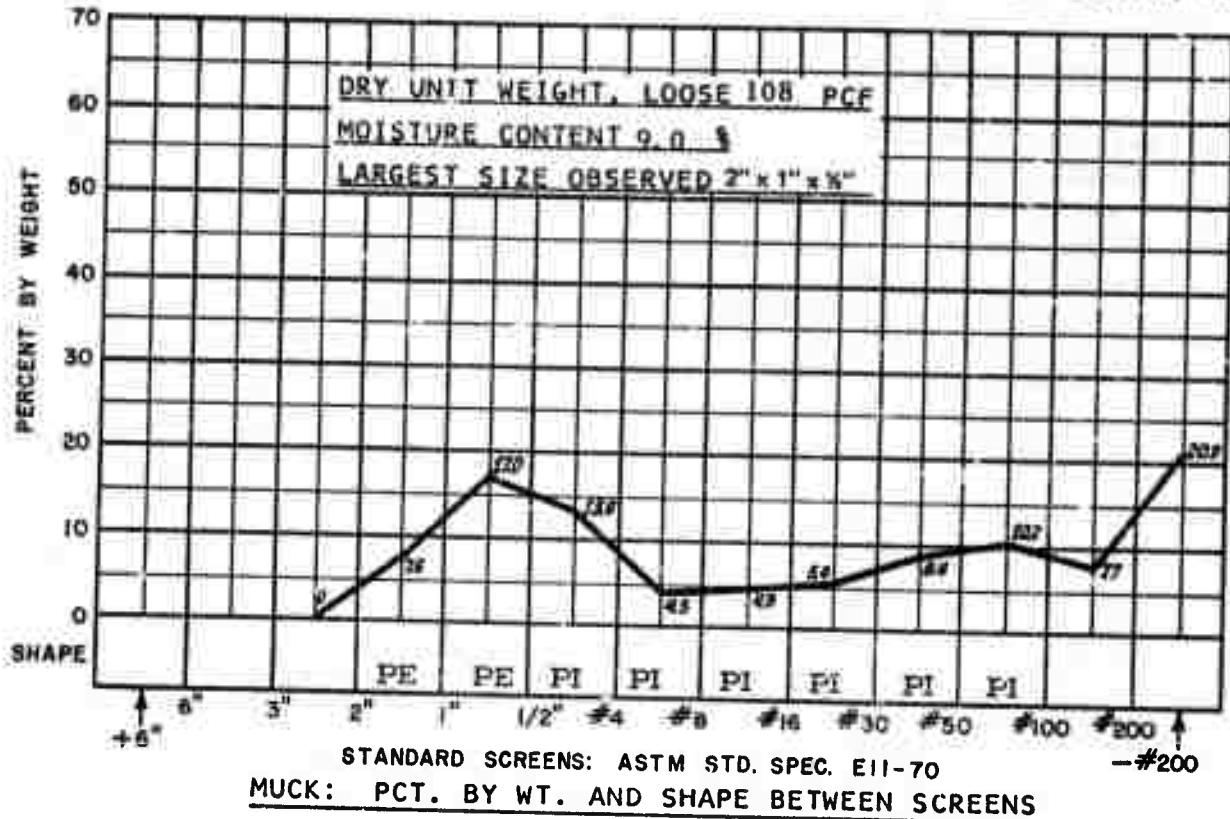
Abrasiveness N. A.	Pot. Vol. Change, Material Size (-) 0.056": 0	Spec. Gravity, Material Size (-) 0.75": 2.57
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ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 24.0 %	Plastic Limit 23.3 %	Shrinkage Limit 22.7 %
Plasticity Index 0.7 %	Toughness Index 0.17 %	Flow Index 4.0 %

MATERIAL SIZE (-)2.0 IN.

Angle/Repose 1" Drop @ 9.8 % Moisture, 39°	Apparent Cohesion PSF @ 9.3 % Moisture, 125	Angle/Repose 10" Drop @ 9.8 % Moisture, 37°
Angle Slide Steel Plate @ 8.4 % Moisture, 40°	Bulk Density PCF @ 0.0 % Moisture, 75	Angle Internal Friction @ 9.3 % Moisture, 30°



SUMMARY

Rock Class: Metamorphic: Mica schist, dense, fine grained to extremely coarse occasional quartz seams. Medium strength. RQD (Est.) 30%. DUW: 165 PCF. Ground water: Minor inflows at fault zones. Hardness: NA.

System Class: TBM, Jarva Mark 11-1100, 11' dia. 36 Reed triple discs. RPM: 10.75. Torque: 244 K ft #. Thrust: 1,134 K#. Mucking: Buckets to belt. Haulage: Rail. Support: Minor, semicircular plates in fault zones.

MDN STUDY
9/1/72

SYSTEM DATA SHEET
MDN

Ident. No. QL-1
Sheet 2

ROCK DATA:

Lithology: Sedimentary, graywacke ("argillaceous quartzite"), massive to medium bedded, highly folded and fractured, normal dip of bedding 30° to 45°.

Uniaxial Compressive Strength: NA.

RQD: (Estimated) 35%.

Dry Unit Weight: NA.

Ground Water: None.

Hardness: NA.

TUNNEL DATA:

Size: 10' wide x 10.8'. Grade: (+) 2%.

Ventilation System: 8 KCFM, exhaust, 16" diameter pipe, 30 HP @ 1800' and pressure auxiliary, 8" pipe, 5 HP @ 100'.

Utility System: 6" air line, 4" water line.

Water Inflow: None.

Power System: 2300/480/120V.

Haulage System: Muck, personnel, supplies by railcars, 30" gage, 80# and 60# rail, 10 ton trolley locomotives, 200 and 140 Cu bottom dump cars to skip pocket, 14 ton skips to surface.

Support System: Roof plates and 3/4" x 6' bolts as required.

EXCAVATION DATA:

Conventional Rail System.

Drilling: Hydrojib jumbo, 2 boom, D93 drifters, 1 1/4" round steel on 10' chain feeds.

Drill Round: 36 holes, 1 5/8" diameter, V cut, 8' depth.

Explosives: 210#, 200# Ammonium Nitrate, 10#-7/8" x 8", 70% in ribs and top. Powder factor, 7.5#/CY.

Blasting: Detaprime primers, caps, fuse and igniter cord.

Mucking System: Eimco Model 40 mucker.

Guidance: Transit Lines.

MUCK DATA

Test Data NA.

Abrasiveness
N. A.Pot. Vol. Change, Material
Size :Spec. Gravity, Material
Size :

ATTERBERG LIMITS, MATERIAL SIZE

IN.

Liquid Limit

%

Plastic Limit

%

Plasticity Index

%

Toughness Index

%

Shrinkage Limit

%

Flow Index

%

MATERIAL SIZE

IN.

Angle/Repose 1" Drop

Apparent Cohesion PSF

Angle/Repose 10" Drop

@ % Moisture,

@ % Moisture,

@ % Moisture,

Angle Slide Steel Plate

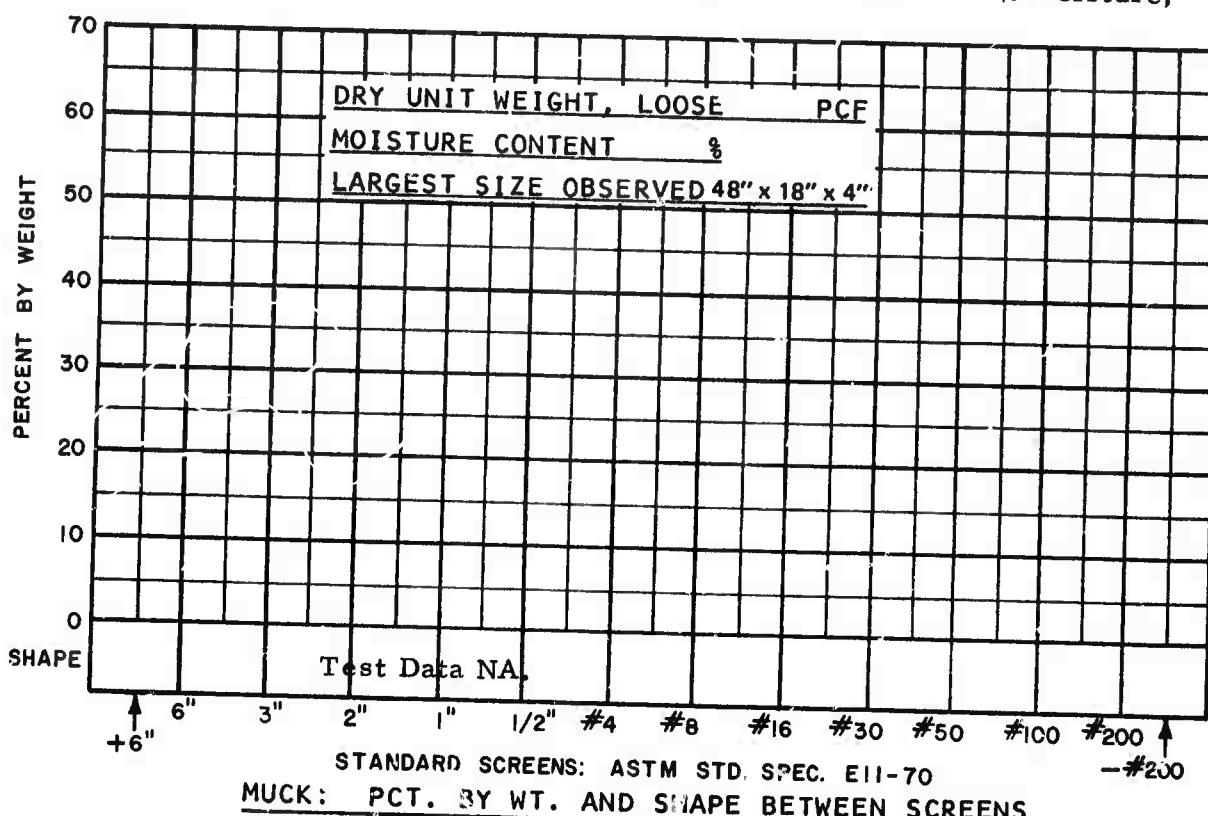
Bulk Density PCF

Angle Internal Friction

@ % Moisture,

@ % Moisture,

@ % Moisture,



SUMMARY

Rock Class: Sedimentary: Graywacke, massive to medium bedded, normal dip 30° to 45°, highly folded and fractured. NA strength. RQD (Est.) 35%.
DUW: NA PCF. Ground water: None. Hardness: NA.

System Class: Conventional rail, 10' wide x 10.8'. Two machine jumbo, 36 - 8' holes, V cut. PF 7.5#/CY. Overhead loader mucking - rail haulage.
Support: Rock bolts and plates as required.

MDN STUDY

9/1/72

SYSTEM DATA SHEET
MDNIdent. No. MB-2
Sheet 2

ROCK DATA:

Lithology. Sedimentary, sandstone, fine grained, well compacted light brown, over 50 percent quartz.
Uniaxial Compressive Strength: 22 KPSI.
RQD: 92%.
Dry Unit Weight: 166 PCF
Ground Water: Dry.
Hardness: Shore 61.

TUNNEL DATA:

Size: 18'-1" dia. Grade (-) 7%
Ventilation System: 17 K CFM, exhaust, 36" dia. pipe, 75 HP @ 4100'.
Utility System: 2" water line, 4" pump line. No air line - compressor on machine.
Water Inflow: 5-10 gpm
Power System: 4160/480V
Haulage System, Muck: 390' of 30" "piggy back" conveyor supported by a monorail advances with the TBM, discharges on a 36" conveyor suspended from the back of the tunnel. Supply and Personnel: Diesel jeeps and trucks.
Support System: 6" x 8.2# channels x 9.5' or 13.5' @ 4' or 2', secured by 4-5/8" x 4' rock bolts. Channels also support monorail.

EXCAVATION DATA:

Machine: Robbins 181-122 Weight: 260 tons.
Cutters: 47 Robbins, Steel Disc. Gage: 3-12". Center: 1-7 1/2" triple, Interior: 43-12".
Rotation: 4 1/2 RPM (Center integral with head)
Torque: 1,720 K ft. #
Thrust: 1,580 K# max., 914 K# operating.
Muck Collection: Buckets fixed to head, discharging on a 30" conveyor.
Power System: Six-480V., 200 HP motors drive head. Hydraulic pumps power thrust and anchor cylinders.
Guidance System: Laser.

MUCK DATA

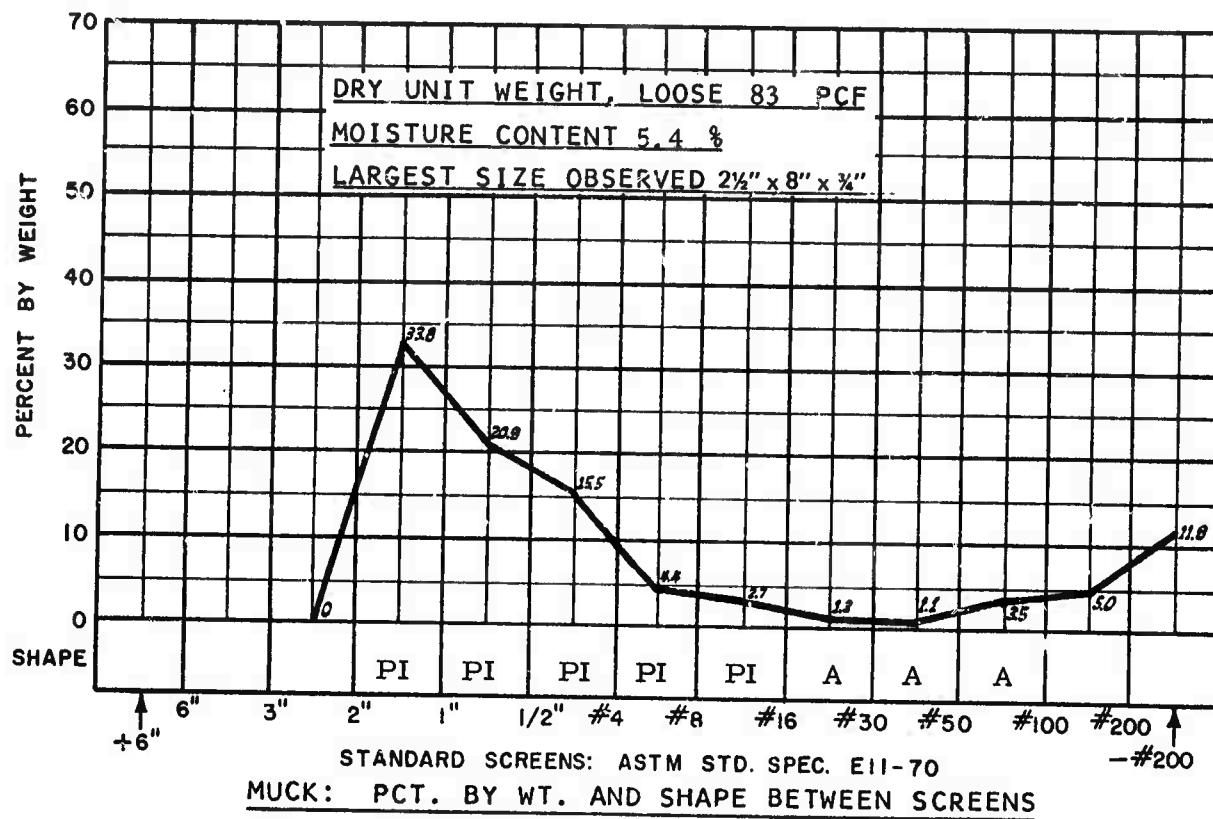
Abrasiveness N. A. Pot. Vol. Change, Material Size (-) 0.065": 0 Spec. Gravity, Material Size (-) 0.75": 2.73

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.185 IN.

Liquid Limit 16.90% Plastic Limit 15.50% Shrinkage Limit 15.8%
Plasticity Index 1.40% Toughness Index 0.28% Flow Index 5.0%

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop @ 6.3 % Moisture, 35°	Apparent Cohesion PSF @ % Moisture, NA	Angle/Repose 10" Drop @ 6.3 % Moisture, 29°
Angle Slide Steel Plate @ 6.3 % Moisture, 28°	Bulk Density PCF @ % Moisture, NA	Angle Internal Friction @ 4.8 % Moisture, 29°



SUMMARY

Rock Class: Sedimentary: Sandstone, fine grained, well compacted, over 50% quartz. High strength. RQD: 92%. DUW: 171 PCF. Ground water: Dry. Hardness: Shore 61.

System Class: TBM, Robbins 181-122, 18' 1" dia. 47 Robbins disc cutters. RPM: 4-1/2, 1,720 K FT. # torque, 914 K# thrust. Mucking: Buckets to belt conveyor. Haulage: Traveling conveyor - suspended conveyor - skip to surface. Support: Channels and rock bolts at 4' or 2', continuous.

MDN STUDY

9/1/72

SYSTEM DATA SHEET

MDN

Ident. No. 5-1

Sheet 2

ROCK DATA:

Lithology: Sedimentary, sandstone, fine grained, well compacted light brown, over 50 percent quartz.

Uniaxial Compressive Strength: 22 KPSI.

RQD: 92%.

Dry Unit Weight: 166 PCF.

Ground Water: Dry.

Hardness: Shore 61.

TUNNEL DATA:

Size: 18'-1" dia. Grade (+) 2%.

Ventilation System: 17 K CFM, exhaust, 36" dia. pipe, 75 HP @ 4800'.

Utility System: 2" water line, 4" pump line. No air line - compressor on machine.

Water Inflow: 5-10 gpm.

Power System: 4160/480V.

Haulage System, Muck: 390' of 30" "piggy back" conveyor supported by a monorail advances with the TBM, discharges on a 36" conveyor suspended from the back of the tunnel. Supply and Personnel: Diesel jeeps and trucks.

Support System: 6" x 8.2# channels x 9.5' or 13.5' @ 4' or 2', secured by 4-5/8" x 4' rock bolts. Channels also support monorail.

EXCAVATION DATA:

Machine: Robbins 181-122 Weight: 260 tons.

Cutters: 47 Robbins, Steel Disc. Gage: 3-12". Center: 1-7 1/2" triple, Interior: 43-12".

Rotation: 4 1/2 RPM (Center integral with head)

Torque: 1,720 Kft #

Thrust 1,580 K# max., 747 K# operating.

Muck Collection: Buckets fixed to head, discharging on a 30" conveyor.

Power System: Four-480V., 200 HP motors drive head. Hydraulic pumps power thrust and anchor cylinders.

Guidance System: Laser.

MUCK DATA

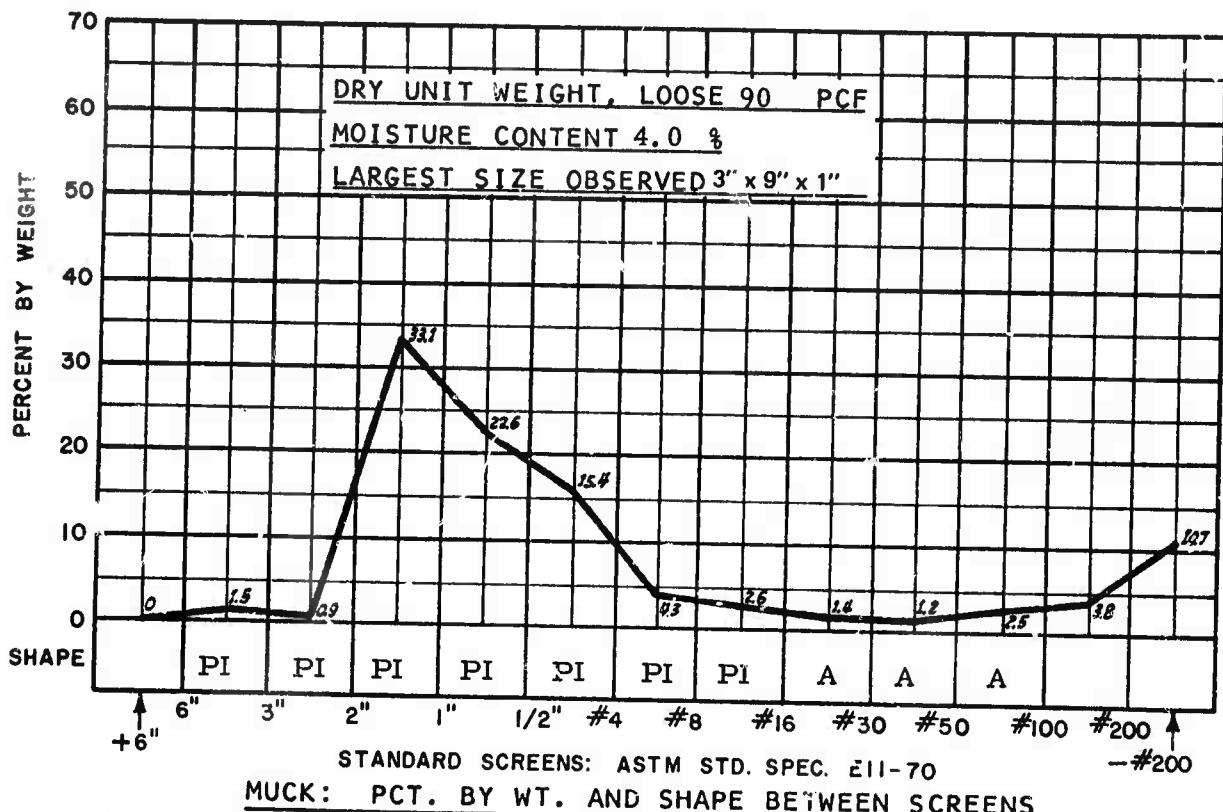
Abrasiveness Pot. Vol. Change, Material
 N. A. Size (-) 0.056": 0 Spec. Gravity, Material
 Size (-) 0.75": 2.63

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 23.0 % Plastic Limit 17.63 % Shrinkage Limit 17.58 %
 Plasticity Index 5.37 % Toughness Index 0.78 % Flow Index 6.90 %

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop @ 2.6 % Moisture, 32°	Apparent Cohesion PSF @ 2.8 % Moisture, 0	Angle/Repose 10" Drop @ 2.6 % Moisture, 31°
Angle Slide Steel Plate @ 2.6 % Moisture, 29°	Bulk Density PCF @ 0.0 % Moisture, 92.8	Angle Internal Friction @ 2.8 % Moisture, 44°



SUMMARY

Rock Class: Sedimentary: Sandstone, fine grained, well compacted, over 50% quartz. High strength. RQD: 92%. DUW: 171 PCF. Ground water: Dry. Hardness: Shore 61.

System Class: TBM, Robbins 181-122, 18'1" dia. 47 Robbins disc cutters. 4-1/2 RPM, 1,720 K FT # torque, 747 K# thrust. Mucking: Buckets to belt conveyor. Haulage: Traveling conveyor - suspended conveyor - skip to surface. Support: Channels and rock bolts at 4' or 2', continuous.

ROCK DATA:

Lithology: Sedimentary, "shale", massive to thinly-laminated, interbedded siltstone and shale, with minor sandstone and limestone layers. Grain size varies from fine to coarse, quartz content from 24 to 33%.

Uniaxial Compressive Strength: Four major beds: 22 K to 29 KPSI, three minor beds: 12 K to 17 KPSI. Weighted Average: 23 KPSI.

RQD: (Estimated) 90%.

Dry Unit Weight: 152 PCF.

Ground Water: Dry

Hardness: Shore 41 to 55 parallel to bedding planes, 41 to 54 perpendicular.

TUNNEL DATA:

Size: 24' wide x 7 1/2' rectangular. Grade: Varies

Ventilation System: 80-100K CFM, pressure

Utility System: 4" air, 4" water, 4" pump, where required.

Water Inflow: Normally none.

Power System: 110V. lighting-all equipment diesel or air powered.

Haulage System: Wagner ST-5 Scooptrams, 16 ton shuttle cars to conveyors, 1 1/2 CY loaders for cleanup. Personnel and supplies, diesel jeeps and trucks.

Support System: 5/8" x 6' rock bolts on 4' x 4' pattern, 11" wide x 10' roof plates where required.

EXCAVATION DATA:

Conventional Trackless System.

Drilling: Two boom hydrojib jumbos, AR93 drifters, 14' feed.

Drill Round: 35 holes, 1 3/4" diameter, 10 1/2 to 11' deep, and 1-6' buster hole, V-cut.

Explosives: 16# -1 1/4" x 8", 75% primers, 32#-1 1/4" x 12" RXL, 60% in lifters, 11# coalite 5Y, 1 1/4" x 12" in back holes, 175# AN/FO in remainder of round. Powder factor: 3.5#/CY.

Blasting: Electrical, MS delays.

Mucking: Wagner ST-5 Scooptrams.

Guidance: Transit/Laser.

MUCK DATA

Abrasiveness
N. A.

Pot. Vol. Change, Material
Size (-) 0.056": 0

Spec. Gravity, Material
Size (-) 0.75": 2.65

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 15.60 %

Plastic Limit 14.81 %

Shrinkage Limit 14.51 %

Plasticity Index 0.79 %

Toughness Index 0.26 %

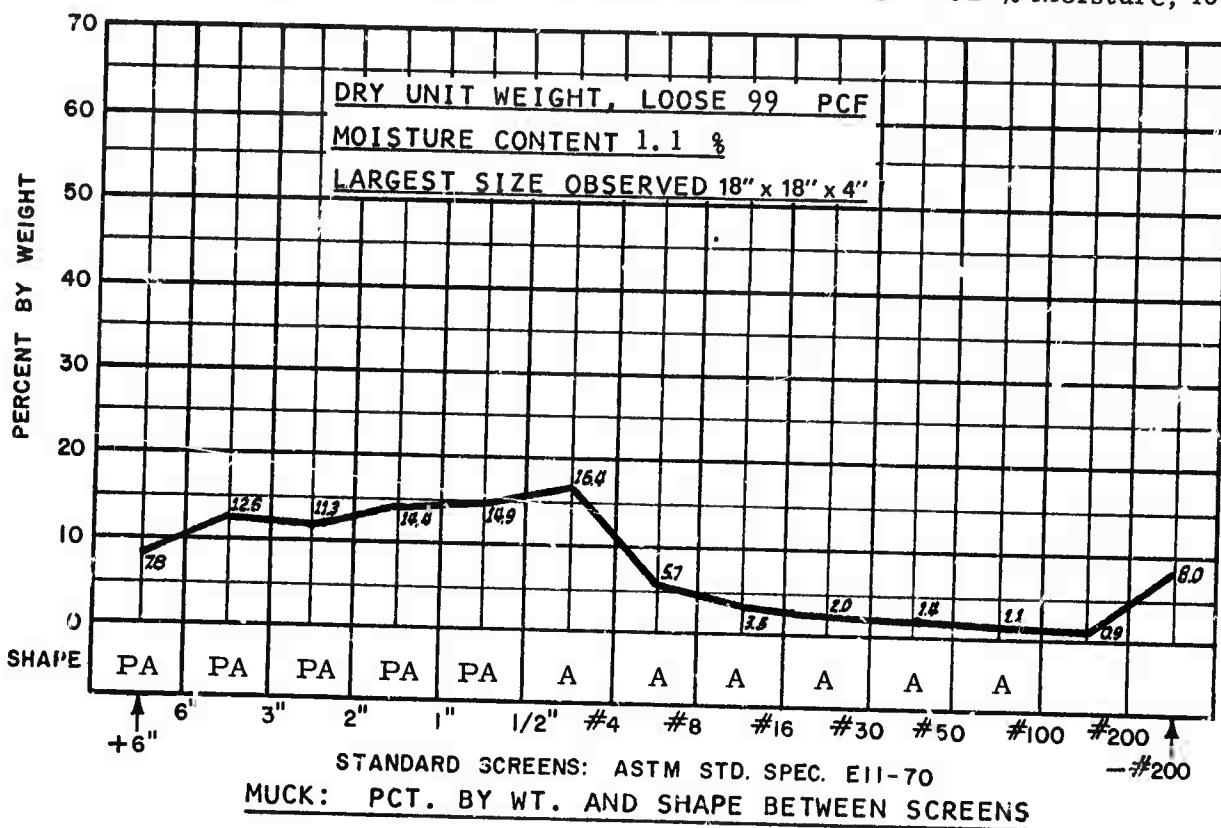
Flow Index 3.00 %

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop
@ 1 % Moisture, 25°
Angle Slide Steel Plate
@ 1 % Moisture, 29°

Apparent Cohesion PSF
@ 0.2 % Moisture, 550
Bulk Density PCF
@ 0.0 % Moisture, 100

Angle/Repose 10" Drop
@ 1 % Moisture, 25°
Angle Internal Friction
@ 0.2 % Moisture, 46°



SUMMARY

Rock Class: Sedimentary: Shale and siltstone, minor sandstone and limestone, thin to massive, fine to coarse grained. High strength. RQD (Est.) 90%. DUW: 152 PCF. Ground water: Dry. Hardness: Shore, 41-55.

System Class: Conventional trackless. 24' wide x 7-1/2', rectangular. Two boom jumbo, 35-1-3/4" holes, V-cut. PF 3.5#/CY. Mucking: Scooptram. Haulage: Scooptram and/or shuttle cars to conveyor. Support: Rock bolts, 4' x 4' pattern.

MDN STUDY

9/1/72

SYSTEM DATA SHEET
MDN

Ident. No. 11-3

Sheet 2

ROCK DATA:

Lithology: Sedimentary, "shale", massive to thinly laminated, interbedded siltstone and shale, with minor sandstone and limestone layers. Grain size varies from fine to coarse, quartz content from 24 to 33%.

Uniaxial Compressive Strength: Four major beds: 22 K to 29 KPSI, three minor beds: 12 K to 17 KPSI. Weighted Average: 22 KPSI.

RQD: (Estimated) 90%.

Dry Unit Weight: 166 PCF.

Ground Water: Dry.

Hardness: Shore 41.0 to 55 parallel to bedding planes, 41 to 54 perpendicular.

TUNNEL DATA:

Size: 18' wide x 8 1/2' high, rectangular. Grade: Level.

Ventilation System: 20 KCFM exhaust from face, pressure to entry, 40 HP.

Utility System: 2" water line (250 cfm compressor on machine trailer).

Water Inflow: None.

Power System: Cable to trailer mounted transformer.

Haulage: Muck by diesel shuttle car to conveyor, personnel and supplies by diesel truck.

Support System: 5/8" rock bolts, normally 6' long on 4' x 4' spacing, as required.

EXCAVATION DATA:

Machine: Atlas-Copco 4 head prototype. Weight: 180 LT. Two 4' dia. heads are mounted on each side of center on horizontal booms rotated about vertical pivots. Heads are rotated around boom centerlines by motors and reducers integral with the booms; booms and heads rotate from side to forward positions.

Cutters: 48 Sandvik T.C., drag type, mounted on head peripheries. Leading cutters, 40mm wide, 8 per head; Finish cutters, 120mm wide, 4 per head.

Rotation: Upper heads: 3 1/4 RPM. Lower: 1 5/8 RPM.

Torque: Head rotation: 80 KW. Boom rotation: 100 LT per boom.

Thrust: 488 LT produced by 4 hydraulic cylinders between advanced and front units.

Anchorage: Two top and two side cylinders, approximately 1,000 K#.

Muck Collection: Flight conveyors move muck from sides to a central 26" flight conveyor, discharging on a 9 1/2' dia. star wheel. The wheel feeds a 25" belt conveyor, transferring muck to a Joy loader and shuttle cars.

Power System: 4160/600/120V, 60 Hz. Head rotation: 4-80 KW motors, hydraulics: 2-78 KW motors, 2300 psi.

Guidance: Transit/Laser.

MUCK DATA

Abrasiveness
N. A.

Pot. Vol. Change, Material
Size (-) 0.056": 0

Spec. Gravity, Material
Size (-) 0.75": 2.78

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 15.80 %
Plasticity Index 0.20 %

Plastic Limit 15.60 %
Toughness Index 0.05 %

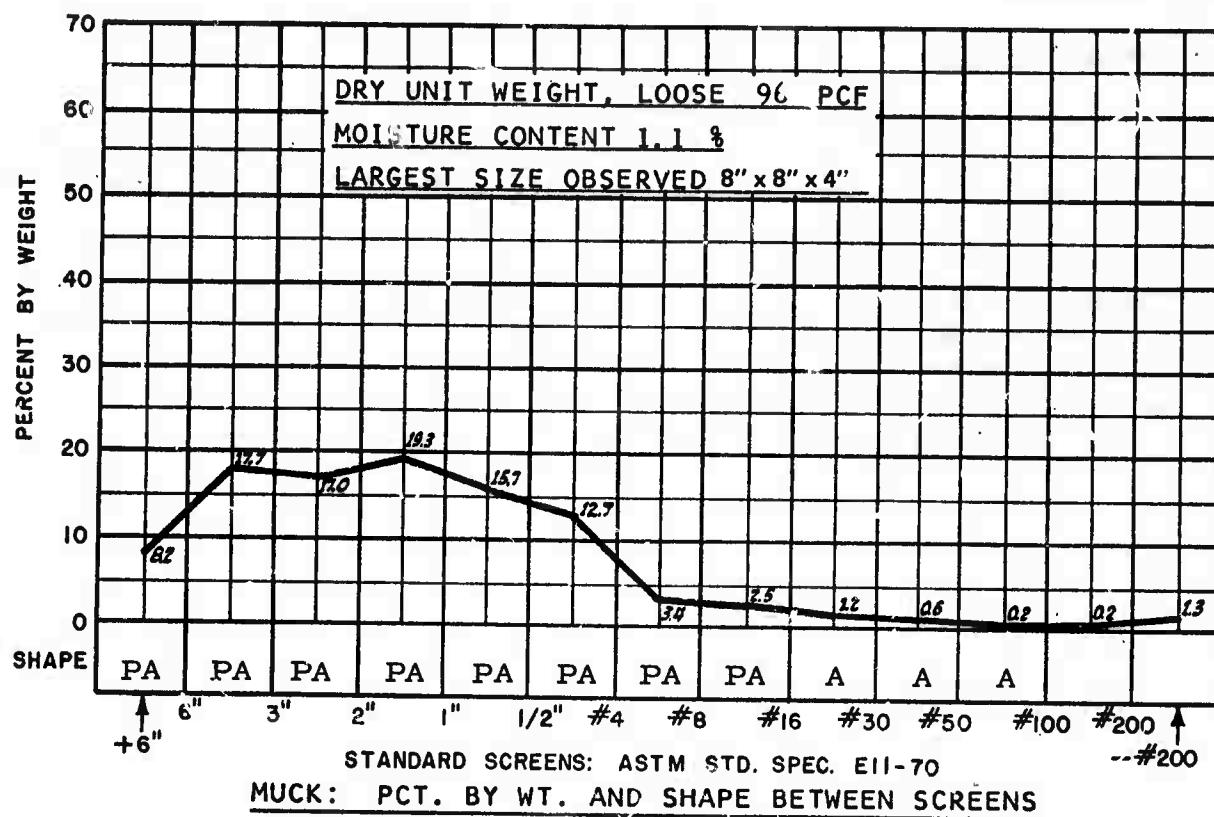
Shrinkage Limit 13.26 %
Flow Index 4.00 %

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop
@ 0.9 % Moisture, 28°
Angle Slide Steel Plate
@ 0.9 % Moisture, 28°

Apparent Cohesion PSF
@ 0.2 % Moisture, 282
Bulk Density PCF
@ 0.0 % Moisture, 100

Angle/Repose 10" Drop
@ 0.9 % Moisture, 29°
Angle Internal Friction
@ 0.2 % Moisture, 54°



SUMMARY

Rock Class: Sedimentary: Shale and siltstone, minor sandstone and limestone, thin to massive, fine to coarse grained. High strength. RQD (Est.) 90%. DUW: 166 PCF. Ground water: Dry. Hardness: Shore 41-55.

System Class: TBM, Atlas-Copco. 18' wide x 8-1/2' rect. heading. Sandvik TC "drag" bits. 12/head, 4 heads. RPM 3 1/4 normal. Torque 80 KW/head, 100LT/boom. 480LT thrust. Mucking: Flight conveyor - starwheel-belt-loader. Haulage: Shuttle car to conveyor. Support: Rock bolts at 4'.

MDN STUDY

9/1/72

SYSTEM DATA SHEET

MDN

Ident. No. 11-4

Sheet 2

ROCK DATA:

Lithology: Sedimentary, "shale", massive to thinly laminated, interbedded siltstone and shale, with minor sandstone and limestone layers. Locally highly faulted and fractured. Grain size varies from fine to coarse.

Uniaxial Compressive Strength: 22K PSI (weighted average).

RQD: (Estimated) 65%.

Dry Unit Weight: 168 PCF.

Ground Water: None.

Hardness: Shore 41 to 55 parallel to bedding planes, 41 to 54 perpendicular.

TUNNEL DATA:

Size: 18'-1" diameter. Grade: (+) 10%.

Ventilation System: 18K CFM, exhaust, 36" diameter pipe, 120 HP @ 7200'.

Utility System: 2" water, 4" pump line from sump at 4200' approximate.

Water Inflow: 5-10 gpm.

Power System: 4160/480V.

Haulage System Muck, 30" - "piggy back" conveyor supported by monorail advances with TBM, feeds a 36" conveyor suspended from back of tunnel.

Supply and Personnel: Diesel jeeps and trucks.

Support System: 6" x 8.2# channels x 13.5' at 2', secured by 6-5/8" x 6" rock bolts, lagging under channels.

EXCAVATION DATA:

Machine: Robbins 181-122. Total weight: 260 tons.

Cutters: 47 Robbins, steel disc, w/Eesco rings, Gage: 3-12".

Center: 1-7 1/2" triple. Interior 43-12".

Rotation: 4 1/2 RPM

Torque: 1,147 K#.

Thrust: 769K#.

Muck System: Buckets fixed to head, discharge on conveyors.

Power System: Four - 480V, 200 HP motors drive head.

Guidance: Laser

MUCK DATA

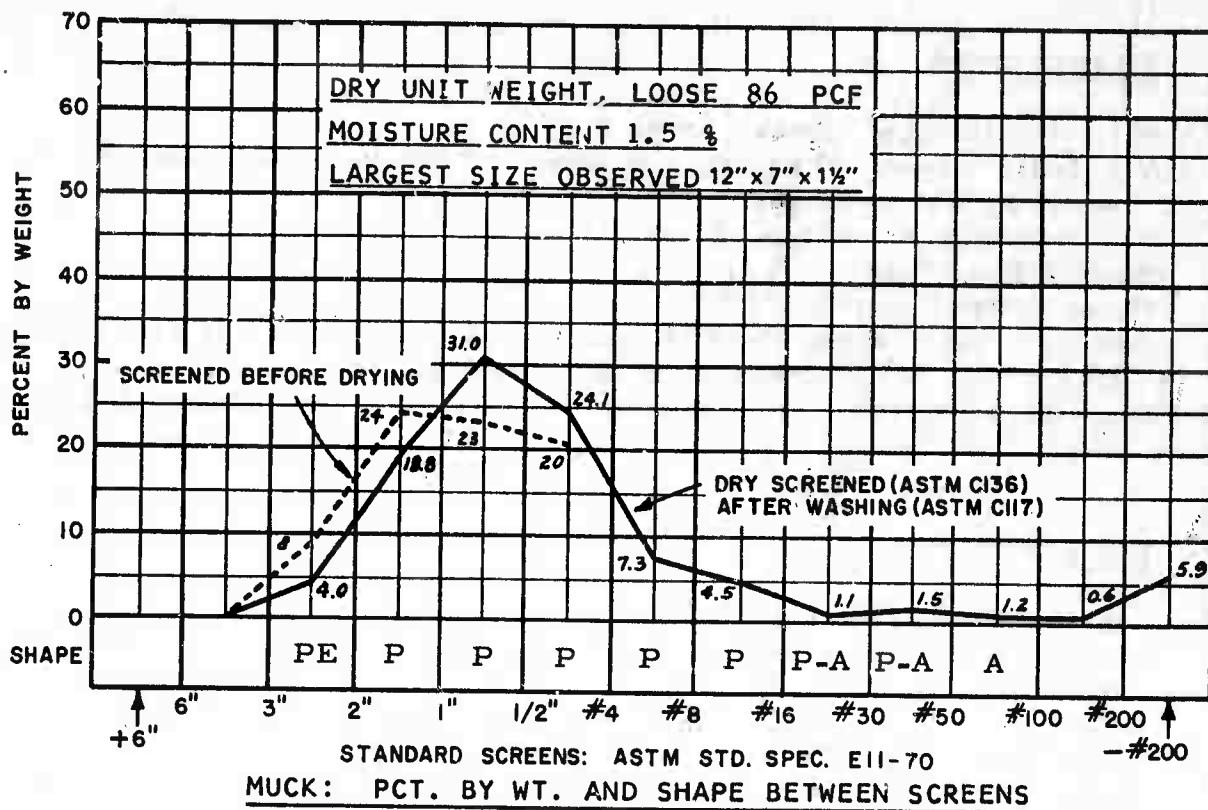
Abrasiveness N. A. Pot. Vol. Change, Material Size (-)0.056" : 0 Spec. Gravity, Material Size (-)0.75" : 2.72

ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 18.00 % Plastic Limit 17.10 % Shrinkage Limit 15.58 %
Plasticity Index 0.90 % Toughness Index 0.20 % Flow Index 4.40 %

MATERIAL SIZE (-)2.0 IN.

Angle/Repose 1" Drop @ 1.3 % Moisture, 36°	Apparent Cohesion PSF @ 1.0 % Moisture, 170	Angle/Repose 10" Drop @ 1.3 % Moisture, 32°
Angle Slide Steel Plate @ 1.3 % Moisture, 30°	Bulk Density PCF @ 0.0 % Moisture, 100	Angle Internal Friction @ 1.0 % Moisture, 41°



SUMMARY

Rock Class: Sedimentary: "Shale" siltstone and shale interbedded, minor sandstone and limestone layers. Massive to thinly laminated, fine to coarse grained. High strength. RQD (Est.) 65%. DUW: 168 PCF. Ground water: None. Hardness: 41 - 55 shore.

System Class: TBM, Robbins 181-122, 18'1" dia. 47 Robbins disc cutters. 4-1/2 RPM, 1,476 K FT # Torque, 769 K# Thrust. Mucking: Buckets to belt.

Haulage: Conveyor.

MDN STUDY

9/1/72

SYSTEM DATA SHEET

MDN

Ident. No. 72-1

Sheet 2

ROCK DATA:

Lithology: Sedimentary, conglomerate ("breccia") 1/4"-10" rounded to angular boulders, cobbles, pebbles in a predominantly limestone matrix, w/chert, schist diabase fragments, well to moderately consolidated.

Uniaxial Compressive Strength: NA.

RQD: (Estimated) 65%.

Dry Unit Weight: 171 PCF

Ground Water: Normally dry.

Hardness: NA.

TUNNEL DATA:

Size: 9' x 10' high. Grade: Level.

Ventilation System: 10 KCFM, pressure, 24" diameter pipe, 50 HP @ 1000', from coil heat exchanger.

Utility System: 6" air line, 2" water line.

Water Inflow: None.

Power System: 4160/480/120V.

Haulage System: Muck, supplies, personnel by railcars, 4 and 6 ton battery locomotives 44 CF rocker dump cars, 18" gage, 30# rail.

Support System: 5/8" x 6' rock bolts, 3', 4 1/2' or 6' roof plates, 21 bolts and 7 plates per 5' span.

EXCAVATION DATA:

Conventional Rail System.

Drilling: 3 boom hydraulic jumbo, 7' chain feeds, and 3" bore drifters, 7/8" hex steel.

Drill Round: 42 to 50-1 3/8" diameter holes including 4 hole V cut and 4 hole baby V or 5 hole burn cut, average advance 5 1/2".

Explosives: 150#, 25# Amogel, #4-40% primers and cushion, 125# Carbamite PB. Powder Factor, 8.2#/CY.

Blasting: #6 caps, 8' fuse, detonated electrically, timed by order of connection to igniter cord.

Mucking System: Eimco Model 21 Loader.

Guidance: Laser

MUCK DATA

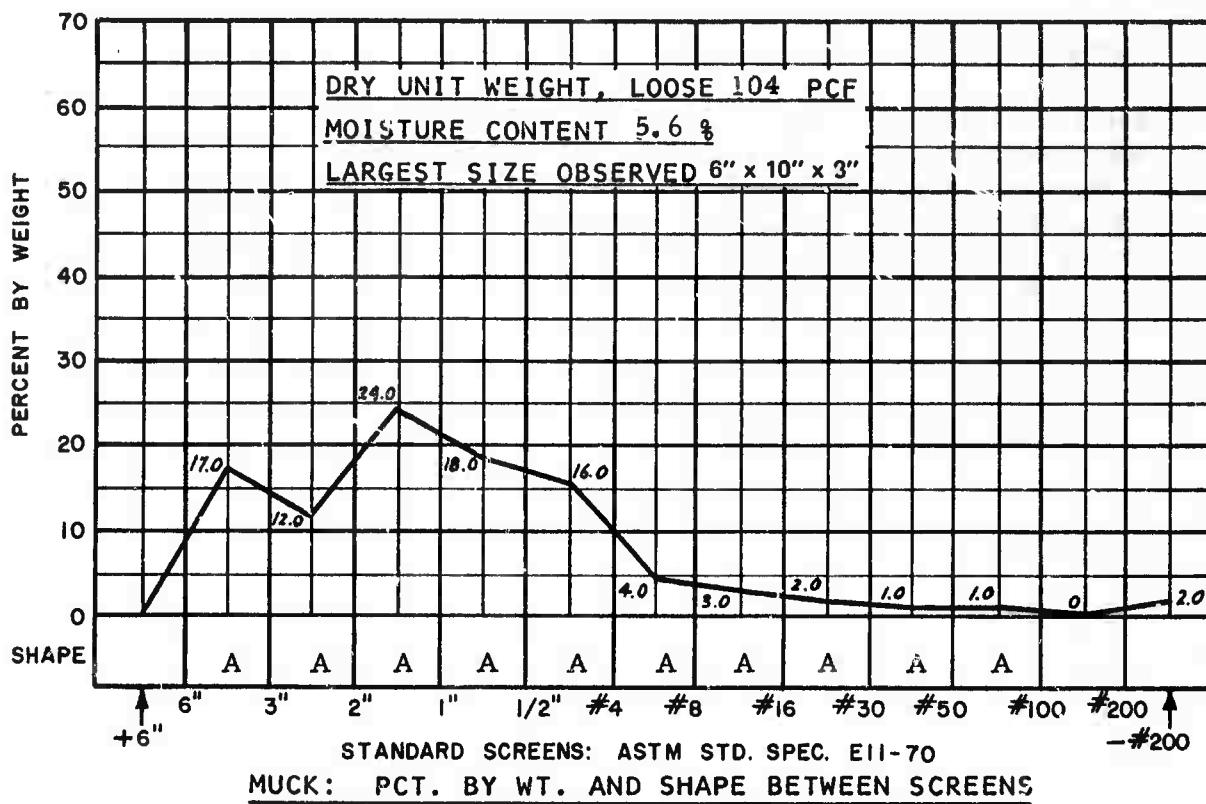
Abrasiveness N. A.	Pot. Vol. Change, Material Size(-) 0.056" : 0	Spec. Gravity, Material Size (-) 0.75" : 2.74
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ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 13.80 %	Plastic Limit 12.77 %	Shrinkage Limit 10.78%
Plasticity Index 1.03 %	Toughness Index 0.32 %	Flow Index 3.20 %

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop @ 0.4 % Moisture, 35°	Apparent Cohesion PSF @ 0.3 % Moisture, 410	Angle/Repose 10" Drop @ 0.4 % Moisture, 29°
Angle Slide Steel Plate @ 0.4 % Moisture, 27°	Bulk Density PCF @ 0.0 % Moisture, 111	Angle Internal Friction @ 0.3 % Moisture, 46°



SUMMARY

Rock Class: Sedimentary: Conglomerate, "breccia," 1/4" to 10", limestone, chert, schist, diabase fragments, well to moderately consolidated. Strength, NA. RQD (Est.) 65%. DUW: 171 PCF. Ground water: Dry. Hardness, NA.

System Class: Conventional Rail, 9' wide x 10', three boom jumbo, 42 to 50-1-3/8" holes, burn cut. PF 8.2#/CY. Mucking: Eimco 21. Haulage: Rail. Support: Rock bolts and plates, continuous.

MDN STUDY

9/1/72

SYSTEM DATA SHEET

MDN

Ident. No. MSU-1

Sheet 2

ROCK DATA:

Lithology: Sedimentary, conglomerate, ("breccia") 1/4"-4" boulders, cobbles, and pebbles, rounded to angular in a predominantly limestone matrix, w/chert, schist and diabase fragments, well consolidated.

Uniaxial Compressive Strength: NA.

RQD: (Estimated) 80%.

Dry Unit Weight: 171 PCF

Ground Water: None

Hardness: NA.

TUNNEL DATA:

Size: 9' wide x 10' high, arched. Grade: Level.

Ventilation System: 9 KCFM, pressure, 24" diameter pipe, 50 HP @ 1300' from coil heat exchanger.

Utility System: 6" air line, 2" water line.

Water Inflow: None.

Power System: 4160/480/120V.

Haulage System: Muck, supplies, personnel by railcars, 4 and 6 ton battery locomotives, 44 cu. ft. rocker dump cars, 18" gage, 30# rail.

Support System: 5/8" x 6' rock bolts, 3', 4 1/2' or 6' roof plates, 21 bolts and 7 plates per 5' span.

EXCAVATION DATA:

Conventional Rail System.

Drilling: 2 boom jumbo, 6' chain feeds and 3" bore drifters.

Drill Round: 50-1 3/8" diameter holes, including 4 hole V cut and 4 hole baby V, 5 1/2' average advance.

Explosives: 122# average, 40% Amogel #4 or 40% primers and carbamite. Powder Factor, 6.7#/CY.

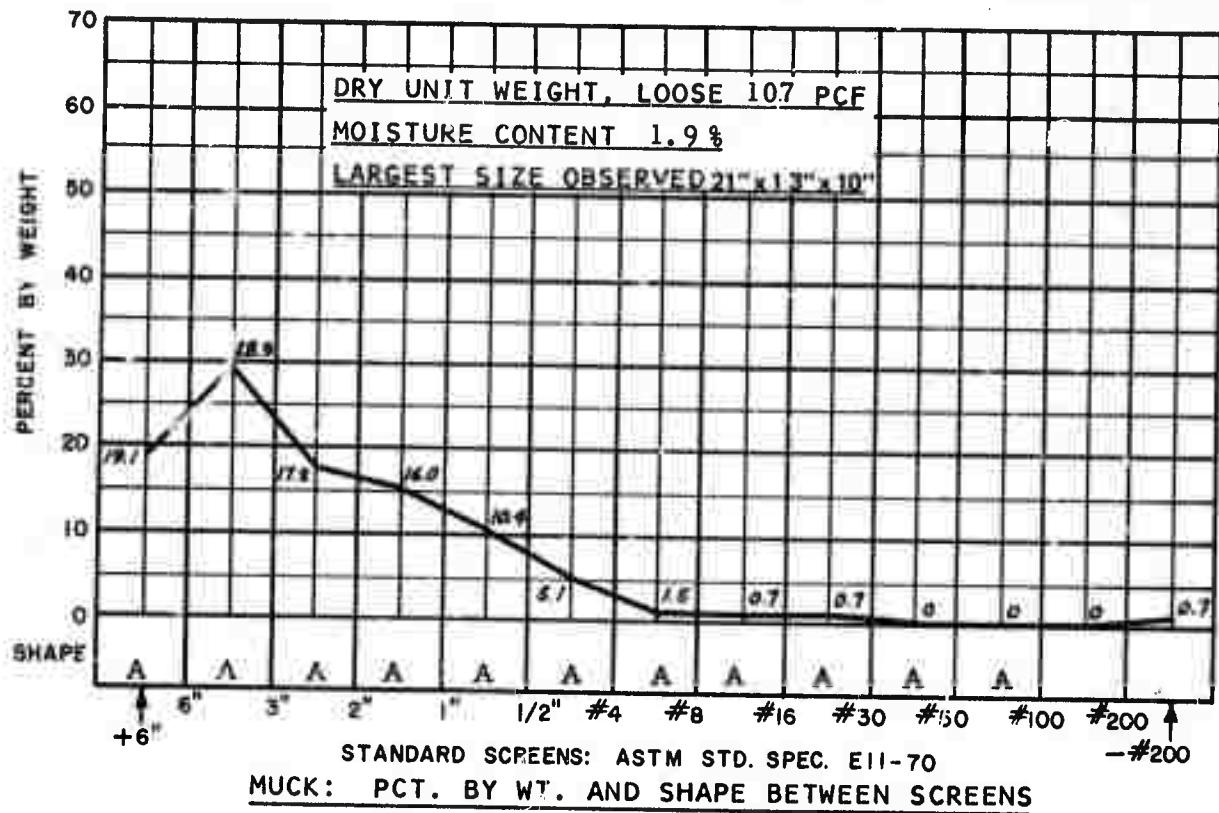
Blasting: #6 caps, 8' fuse, detonated electrically, timed by order of connection to igniter cord.

Mucking System: Eimco Model 21 loader.

Guidance: Laser.

MUCK DATA

Abrasiveness N. A.	Pot. Vol. Change, Material Size : NA	Spec. Gravity, Material Size : NA
ATTERBERG LIMITS, MATERIAL SIZE IN.		
Liquid Limit NA %	Plastic Limit NA %	Shrinkage Limit NA %
Plasticity Index NA %	Toughness Index NA %	Flow Index NA %
MATERIAL SIZE IN.		
Angle/Repose 1" Drop @ % Moisture, NA	Apparent Cohesion PSF @ % Moisture, NA	Angle/Repose 10" Drop @ % Moisture, NA
Angle Slide Steel Plate @ % Moisture, NA	Bulk Density PCF @ % Moisture, NA	Angle Internal Friction @ % Moisture, NA



SUMMARY

Rock Class: Sedimentary: Conglomerate, "breccia," 1/4" - 4" limestone, chert schist, diabase fragments, well consolidated. Strength: NA. RQD (Est.) 80%. DUW: 171 PCF. Ground water: None. Hardness: NA.

System Class: Conventional Rail. 9' wide x 10'. Two machine jumbo, 50 holes, V cut. PF 6.7#/CY. Mucking: Eimco 21. Haulage: Rail. Support: Roof plates and rock bolts, continuous.

MDN STUDY
9/1/72

SYSTEM DATA SHEET
MDN

Ident. No. MSU-2
Sheet 2

ROCK DATA:

Lithology: Sedimentary, limestone, light to medium gray, fine grained, some chert nodules, traces to occasional clay partings.

Uniaxial Compressive Strength: 19 KPSI

RQD: (Estimated) 100 percent.

Dry Unit Weight: 160 PCF.

Ground Water: Table above tunnel, occasional seepage from minor fractures and faults.

Hardness: Shore, 46.

TUNNEL DATA:

Size: 13'-8' diameter. Grade (+) 1/4 percent.

Ventilation System: 21 K CFM exhaust, 28" pipe.

Utility System: 6" air line, 2" water line, 6" pump line.

Water Inflow: 40 to 120 gpm.

Power System: 4160/480V.

Haulage System: Muck, supplies, personnel, by rail cars.

Support System: None.

EXCAVATION DATA:

Machine: Alkirk Hardrock. Weight 400 tons. Cutters: 28-Lawrence Mfg. Company, Tungsten Carbide Button, roller, disc, and tricone. Gage: 5-15" TCB roller. Center: 1-24" TCB tricone. Interior: 11-15" TCB disc., 11-15" TCB roller.

Rotation: Center cutter-30 RPM, Head-9 RPM.

Torque: Head 206 K ft. #

Thrust: 614 K# operating

Muck Collection: Buckets from face discharging on 24" belt conveyor.

Power System: Electro-Hydraulic. Total HP: 910.

Guidance System: Laser.

MUCK DATA

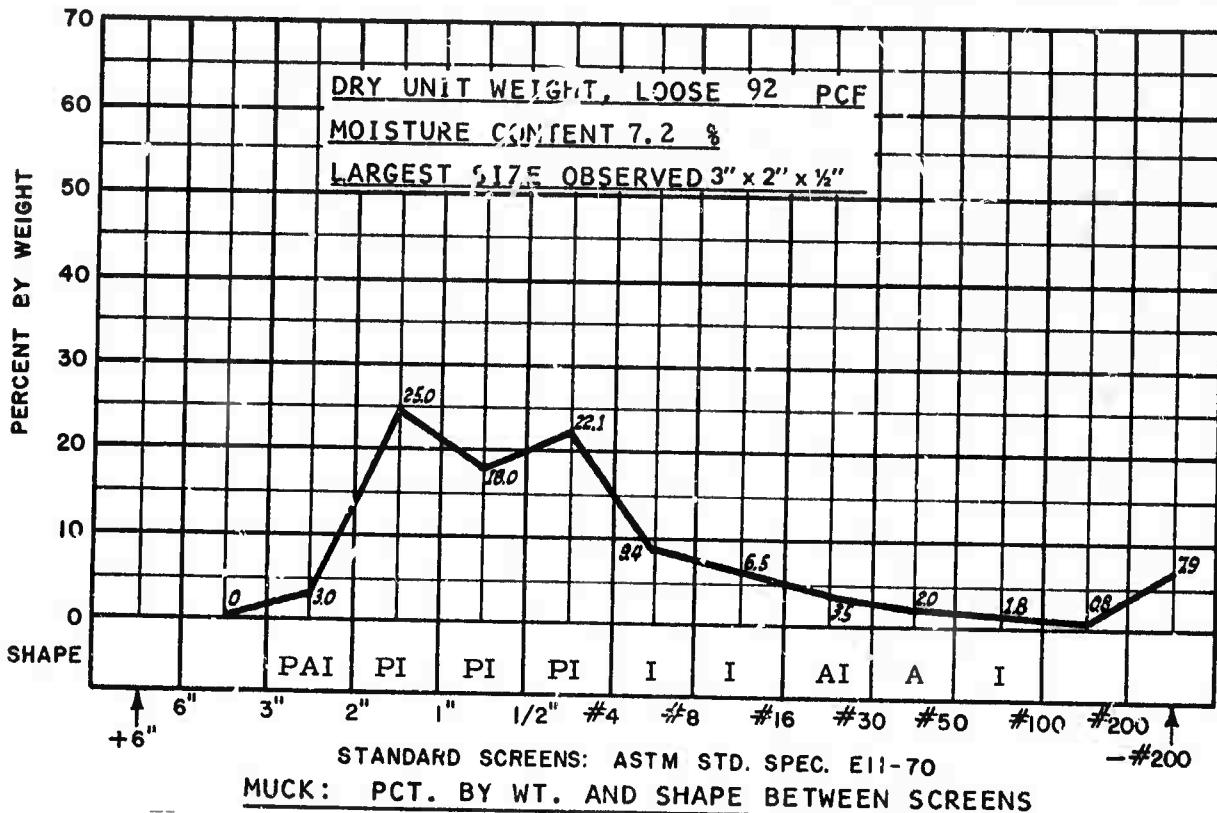
Abrasiveness N. A. Pot. Vol. Change, Material Size (-) 0.065": 0 Spec. Gravity, Material Size (-) 0.75". 2.83

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.185 IN.

Liquid Limit 12.5 % Plastic Limit 12.3 % Shrinkage Limit 9.6 %
Plasticity Index 0.2 % Toughness Index 0.05 % Flow Index 4.0 %

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop @ 5.4 % Moisture, 39°	Apparent Cohesion PSF @ % Moisture, NA	Angle/Repose 10" Drop @ 5.4 % Moisture, 38°
Angle Slide Steel Plate @ 5.4 % Moisture, 31°	Bulk Density PCF @ % Moisture, NA	Angle Internal Friction @ 7 % Moisture, 30°



SUMMARY

Rock Class: Sedimentary: Limestone, fine grained, some chert nodules, occasional clay partings. High strength. RQD (Est.) 100%. DUW: 160 PCF.
Ground water: Minor. Hardness: Shore 46.

System Class: TBM, Alkirk Hardrock, 13' 8" dia. 28 Lawrence TCB roller, disc, tricone cutters. RPM: Center 30, head 9. Torque: 206 K ft #. Thrust: 614 K #. Mucking: Buckets to belt. Haulage: Rail. Support: None.

MDN STUDY
9/1/72

SYSTEM DATA SHEET
MDN

Ident. No. LAW-2
Sheet 2

ROCK DATA:

Lithology: Sedimentary, limestone, light to medium gray, fine grained, some chert nodules, traces to occasional clay partings.
Uniaxial Compressive Strength: 19 KPSI.
RQD: (Estimated) 100 percent.
Dry Unit Weight: 160 PCF.
Ground Water: Table above tunnel, occasional seepage from minor fractures and faults.
Hardness: Shore, 46.

TUNNEL DATA:

Size: 13'-8" diameter. Grade (+) 1/4 percent.
Ventilation System: 20 K CFM exhaust, 28" pipe.
Utility System: 6" air line, 2" water line, 6" pump line.
Water Inflow: 40 to 120 gpm.
Power System: 4160/480V.
Haulage System: Muck, supplies, personnel, by rail cars.
Support System: None.

EXCAVATION DATA:

Machine: Alkirk Hardrock. Weight 400 tons. Cutters: 28-Lawrence Mfg. Company, Tungsten Carbide Button, roller, disc, and tricone. Gage: 5-15" TCB roller. Center: 1-24" TCB tricone. Interior: 11-15" TCB disc., 11-15" TCB roller.
Rotation: Center cutter-30 RPM, Head-9 RPM.
Torque: 206 K ft. #.
Thrust: 614 K# operating.
Muck Collection: Buckets from face, discharging on 24" belt conveyor.
Power System: Electro-Hydraulic. Total HP: 910.
Guidance System: Laser.

MUCK DATA

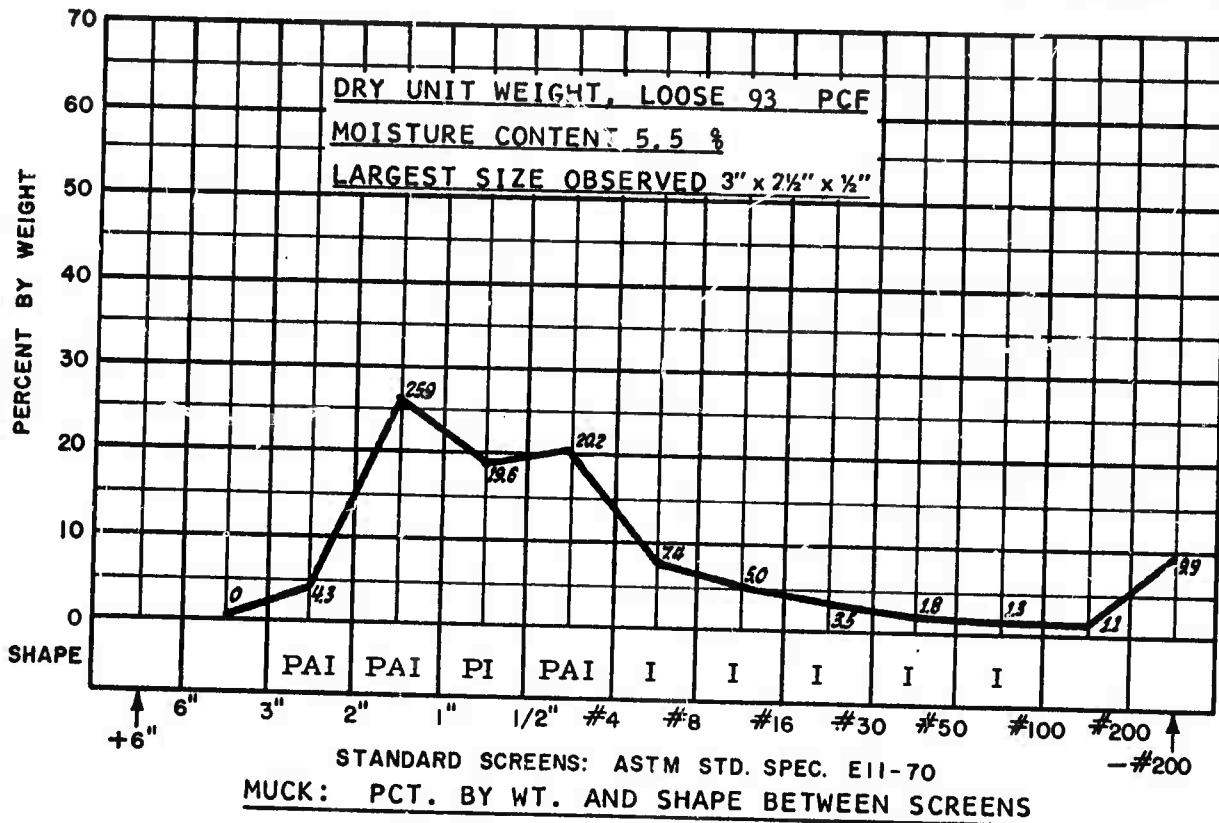
Abrasiveness N. A. Pot. Vol. Change, Material Size (-) 0.065": 0 Spec. Gravity, Material Size (-) 0.75": 2.80

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.185 IN.

Liquid Limit 11.8 % Plastic Limit 10.6 % Shrinkage Limit 10.0 %
Plasticity Index 1.2 % Toughness Index 0.41 % Flow Index 2.9 %

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop @ 6.1% Moisture, 41°	Apparent Cohesion PSF @ % Moisture, NA	Angle/Repose 10" Drop @ 6.1 % Moisture, 40°
Angle Slide Steel Plate @ 8.4 % Moisture, 38°	Bulk Density PCF @ % Moisture, NA	Angle Internal Friction @ 7 % Moisture, 32°



SUMMARY

Rock Class: Sedimentary: Limestone, fine grained, some chert nodules occasional clay partings. High strength. RQD (Est.) 100%. DUW: 160 PCF.
Ground water: Minor. Hardness: Shore 46.

System Class: TBM, Alkirk Hardrock, 13' 8" dia. 28 Lawrence TCB roller, disc, tricone cutters. RPM: Center 30, head 9. Torque: 206 K ft #. Thrust: 614 K#. Mucking: Buckets to belt. Haulage: Rail. Support: None.

MDN STUDY
9/1/72

SYSTEM DATA SHEET
MDN

Ident. No. LAW-3
Sh. et 2

ROCK DATA:

Lithology: Sedimentary, limestone, light to medium gray, fine grained, some chert nodules, traces to occasional clay partings.
Uniaxial Compressive Strength: 19 KPSI.
RQD: (Estimated) 100 percent.
Dry Unit Weight: 160 PCF.
Ground Water: Table above tunnel, occasional seepage from minor fractures and faults.
Hardness: Shore, 46.

TUNNEL DATA:

Size: 13'-8" diameter. Grade (+) 1/4 percent.
Ventilation System: 21 K CFM exhaust, 28" pipe.
Utility System: 6" air line, 2" water line, 6" pump line.
Water Inflow: 40 to 120 gpm.
Power System: 4160/480V.
Haulage System: Muck, supplies, personnel, by rail cars.
Support System: None.

EXCAVATION DATA:

Machine: Alkirk Hardrock. Weight 400 tons. Cutters: 28-Lawrence Mfg. Company, Tungsten Carbide Button, roller, disc, and tricone.
Gage: 5-15" TCB roller. Center: 1-24" TCB tricone. Interior: 11-15" TCB disc., 11-15" TCB roller.
Rotation: Center cutter-30 RPM, Head-9 RPM.
Torque: Head 206 K ft. #.
Thrust: 540 K ft. #.
Muck Collection: Buckets from face discharging on 24" belt conveyor.
Power System: Electro-Hydraulic. Total HP: 910.
Guidance System: Laser.

MUCK DATA

Abrasiveness
N. A.

Pot. Vol. Change, Material
Size (-) 0.056": 0

Spec. Gravity, Material
Size (-) 0.75": 2.73

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 20.2 %
Plasticity Index 0.2 %

Plastic Limit 20.0 %
Toughness Index 0.05 %

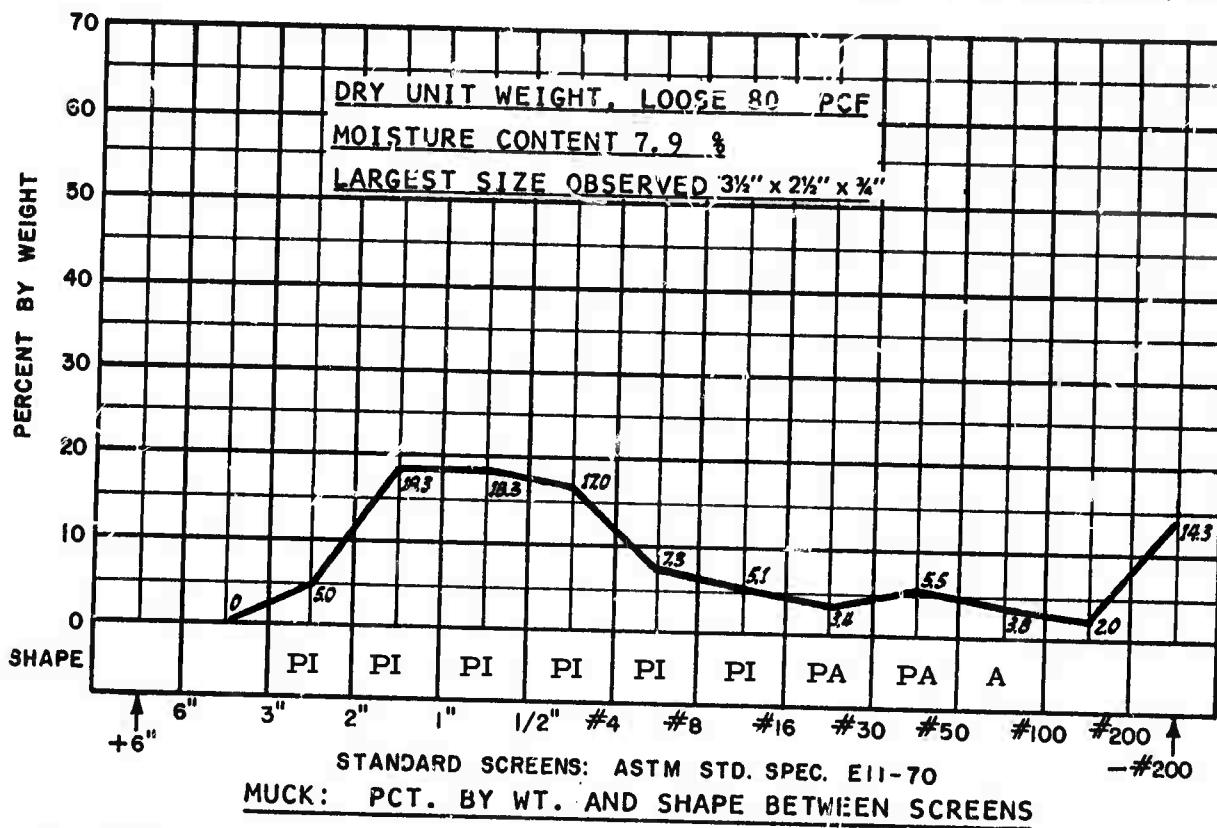
Shrinkage Limit 13.5 %
Flow Index 4.7 %

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop
@ 8.9 % Moisture, 42°
Angle Slide Steel Plate
@ 8.9 % Moisture, 37°

Apparent Cohesion PSF
@ % Moisture, NA
Bulk Density PCF
@ % Moisture, NA

Angle/Repose 10" Drop
@ 8.9 % Moisture, 34°
Angle Internal Friction
@ 8.8 % Moisture, 28°



SUMMARY

Rock Class: Sedimentary: Limestone, fine grained, some chert nodules, occasional clay partings. High strength. RQD (Est.) 100%. DUW: 160 PCF.
Ground water: Minor. Hardness: Shore 46.

System Class: TBM, Alkirk hardrock, 13' 8" dia. 28 Lawrence TCB roller, disc, tricone cutters. RPM: Center 30, head 9. Torque: 206 K ft #. Thrust: 540 K #. Mucking: Buckets to belt. Haulage: Rail. Support: None.

MDN STUDY

9/1/72

SYSTEM DATA SHEET
MDN

Ident. No. LAW-4
Sheet 2

ROCK DATA:

Lithology: Sedimentary, limestone, gray, fine grained, horizontal joint spacing 6" to 1'.

Uniaxial Compressive Strength: 36 KPSI.

RQD: (Estimated) 85%

Dry Unit Weight: 166 PCF.

Ground Water: Minor, in fault zones.

Hardness: NA

TUNNEL DATA:

Size: 11'-2" round. Grade: (+) .2%.

Ventilation System: 4 KCFM, exhaust, 18" pipe, 25 HP.

Utility System: 6" air line, 1" water line, 6" pump line.

Water Inflow: 5-10 gpm.

Power System: 4680/440V.

Haulage System: Muck, supplies, personnel, rail cars, 5 ton motors, track gage 24".

Support System: 4" H rings sets in fault zones, occasional pinned steel lagging.

EXCAVATION DATA:

Machine: Jarva Mark 11-1100. Total weight: 65 tons.

Cutters: 27 Reed steel triple disc and cone. Gage: 4-QK5 steel disc.

Center: 1-QK1 steel cone. Interior: 22-QK3 steel disc.

Rotation: Cutterhead RPM 9.3.

Torque: Maximum 170 K ft#.

Thrust: 1,104 K# maximum, 596 K #-operating. Anchor Pressure: 1,650 K#.

Muck Collection: Bucket from face to 18" belt to 24" belt on gantry.

Power System: 440 volt, 6 - 50 HP motors drive head and 1-40 HP motor for hydraulic system.

Guidance: Laser.

MUCK DATA

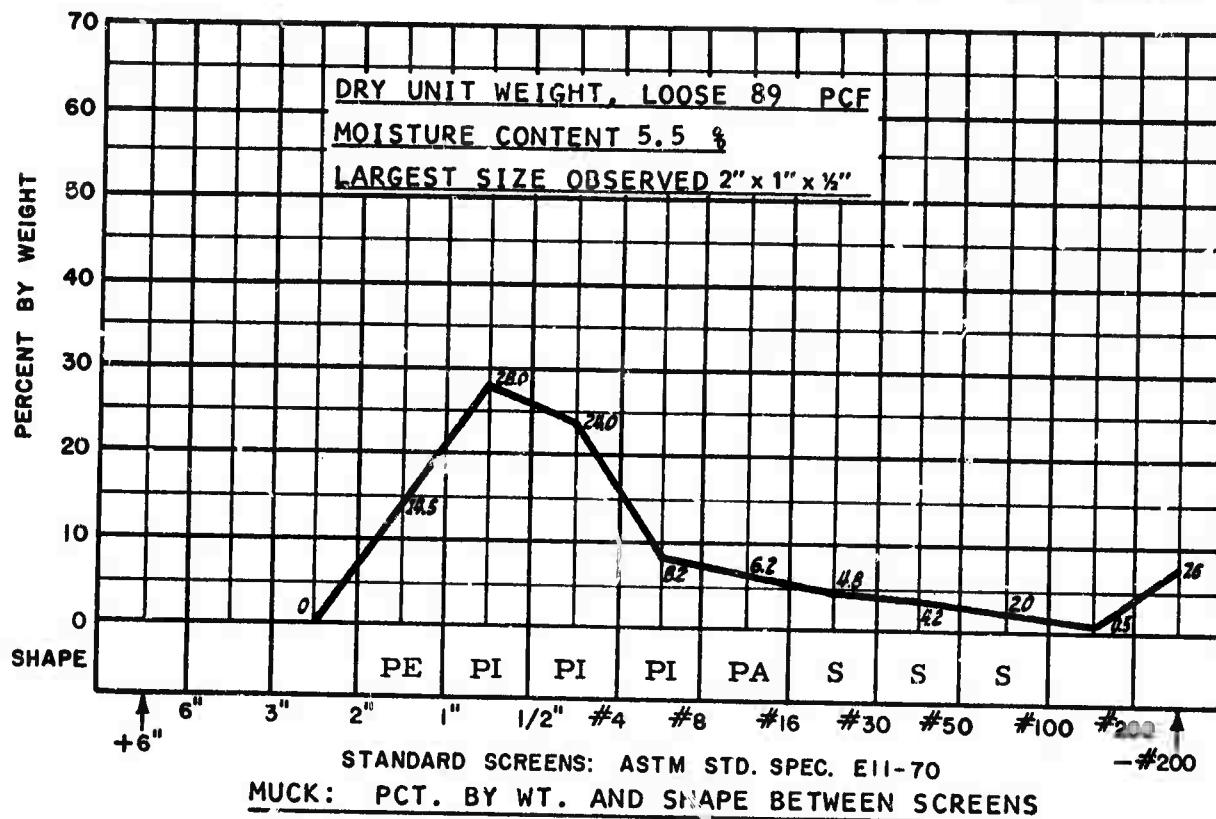
Abrasiveness N. A. Pot. Vol. Change, Material Size (-) 0.056": 0 Spec. Gravity, Material Size (-) 0.75": 2.89

ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 16.90% Plastic Limit 15.69% Shrinkage Limit 15.46%
Plasticity Index 1.21% Toughness Index 0.24% Flow Index 5.00%

MATERIAL SIZE (-)2.0 IN.

Angle/Repose 1" Drop @ 2.5 % Moisture, 36°	Apparent Cohesion PSF @ 4.1 % Moisture, 95	Angle/Repose 10" Drop @ 2.5 % Moisture, 35°
Angle Slide Steel Plate @ 2.5 % Moisture, 30°	Bulk Density PCF @ 0.0 % Moisture, 86	Angl. Internal Friction @ 3.5 % Moisture, 35°



SUMMARY

Rock Class: Sedimentary: Limestone, fine grained, horizontal joint spacing 6" to 1'. Strength: Very high. RQD(Est.) 85%. DUW: 166 PCF.
Ground water: Minor. Hardness: NA.

System Class: TBM, Jarva Mark 11-100, 11' 2" dia. 27 Reed triple disc cutters/cone.
RPM: 9.3. Torque: 170 K ft #. Thrust: 596 K #. Mucking: Bucket to belt.
Haulage: Rail. Support: H ring sets in fault zones.

MDN STUDY
9/1/72

SYSTEM DATA SHEET
MDN

Ident. No. MIL-1
Sheet 2

ROCK DATA:

Lithology: Sedimentary, limestone, gray, fine grained, horizontal joint spacing 6" to 1".

Uniaxial Compressive Strength: 36 KPSI.

RQD: (Estimated) 85%

Dry Unit Weight: 166 PCF.

Ground Water: Minor, in fault zones.

Hardness: NA

TUNNEL DATA:

Size: 11'2" round, Grade: (+) .2%.

Ventilation System: 4KCFM, exhaust, 18" pipe, 25 HP.

Utility System: 6" air line, 1" water line, 6" pump line.

Water Inflow: 5-10 gpm.

Power System: 4680/440V.

Haulage System: Muck, supplies, personnel, rail cars, 5 ton motors, track gage 24".

Support System: 4" H rings sets in fault zones, occasional pinned steel lagging.

EXCAVATION DATA:

Machine: Jarva 11-1100, Total weight: 65 tons.

Cutters: 27 Reed steel triple disc and cone. Gage: 4-QK5 steel disc.

Center: 1-QK1 steel cone. Interior: 22-QK3 steel disc.

Rotation: Cutterhead RPM 9.3.

Torque: Maximum 170 K ft. #.

Thrust: 1,104 K# maximum, 596 K#-operating Anchor Pressure: 1,650 K#.

Muck Collection: Bucket from face to 18" belt to 24" belt on ganty.

Power System: 440 volt, 6-50 HP motors drive head and 1-40 HP motor for hydraulic system.

Guidance: Laser.

MUCK DATA

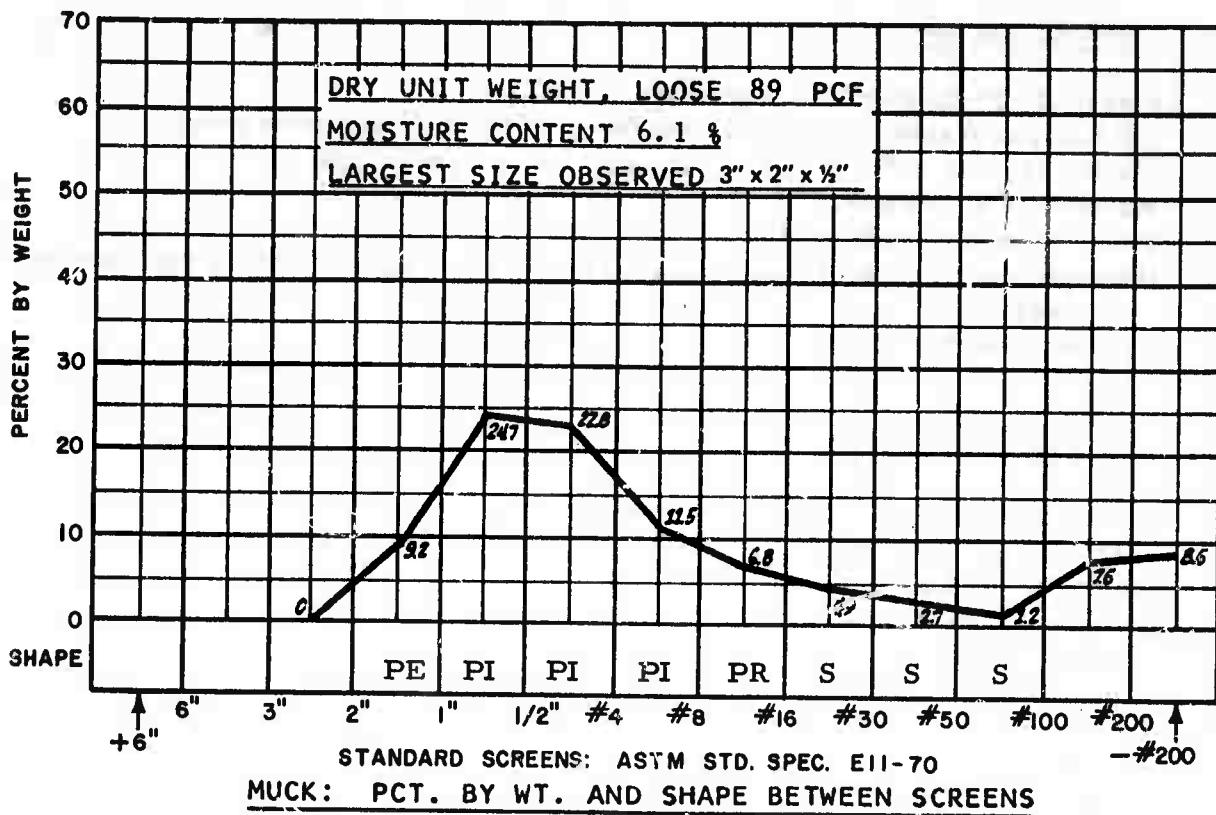
Abrasiveness Pot. Vol. Change, Material
 N. A. Size (-) 0.056": 0 Spec. Gravity, Material
 Size (-) 0.75": 2.93

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 20.10% Plastic Limit 16.68 % Shrinkage Limit 16.37 %
 Plasticity Index 3.42% Toughness Index 0.56% Flow Index 6.10 %

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop @ 5.8 % Moisture, 32°	Apparent Cohesion PSF @ 5.0 % Moisture, 110	Angle/Repose 10" Drop @ 5.8 % Moisture, 30°
Angle Slide Steel Plate @ 5.8 % Moisture, 30°	Bulk Density PCF @ 0.0 % Moisture, 90	Angle Internal Friction @ 5.0 % Moisture, 33°



SUMMARY

Rock Class: Sedimentary: Limestone, fine grained, horizontal joint spacing 6" to 1'. Strength: Very high. RQD (Est.) 85%. DUW: 166 PCF. Ground water: Minor. Hardness: NA.

System Class: TBM, Jarva Mark 11-100, 11'2" dia. 27 Reed triple disc cutters. RPM: 9.3. Torque: 170 K ft #. Thrust: 596 K#. Mucking: Bucket to belt. Haulage: Rail. Support: H ring sets in fault zones.

MDN STUDY

9/1/72

SYSTEM DATA SHEET

MDN

Ident. No. MIL-2

Sheet 2

ROCK DATA:

Lithology: Sedimentary, limestone, grey, fine grained, horizontal joint spacing 4"-8".
Uniaxial Compressive Strength: 24K PSI.
RQD: (Estimated) 81%.
Dry Unit Weight: 164 PCF
Ground Water: Dry.
Hardness: NA.

TUNNEL DATA:

Size: 11' 2" diameter. Grade: (+) 0.2%.
Ventilation System: 4 KCFM, exhaust, 25 HP (through bore hole).
Utility System: 6" air line, 1" water line, 6" pump line.
Water Inflow: Minor.
Power System: 4680/440V.
Haulage System: Muck, supplies, personnel by railcars, 5 ton locomotive, 24" gage.
Support System: None.

EXCAVATION DATA:

Machine: Jarva, 11-1100, total weight 65 tons.
Cutters: 27 Reed steel disc: 4 gage QK5, 22 interior 2K3, 1 center QK1.
Rotation: 9.3 RPM.
Torque: 119K ft. lbs.
Thrust: 639K#
Muck Collection System: Buckets from face, belt to rear.
Power System: 6-50 HP motors drivehead, 1-40 HP motor for hydraulic system.
Guidance: Laser.

MUCK DATA

Abrasiveness
N. A.

Pot. Vol. Change, Material
Size (-) 0.056": 0

Spec. Gravity, Material
Size (-) 0.75": 2.78

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 15.20 %
Plasticity Index 0.80 %

Plastic Limit 14.40 %
Toughness Index 0.22 %

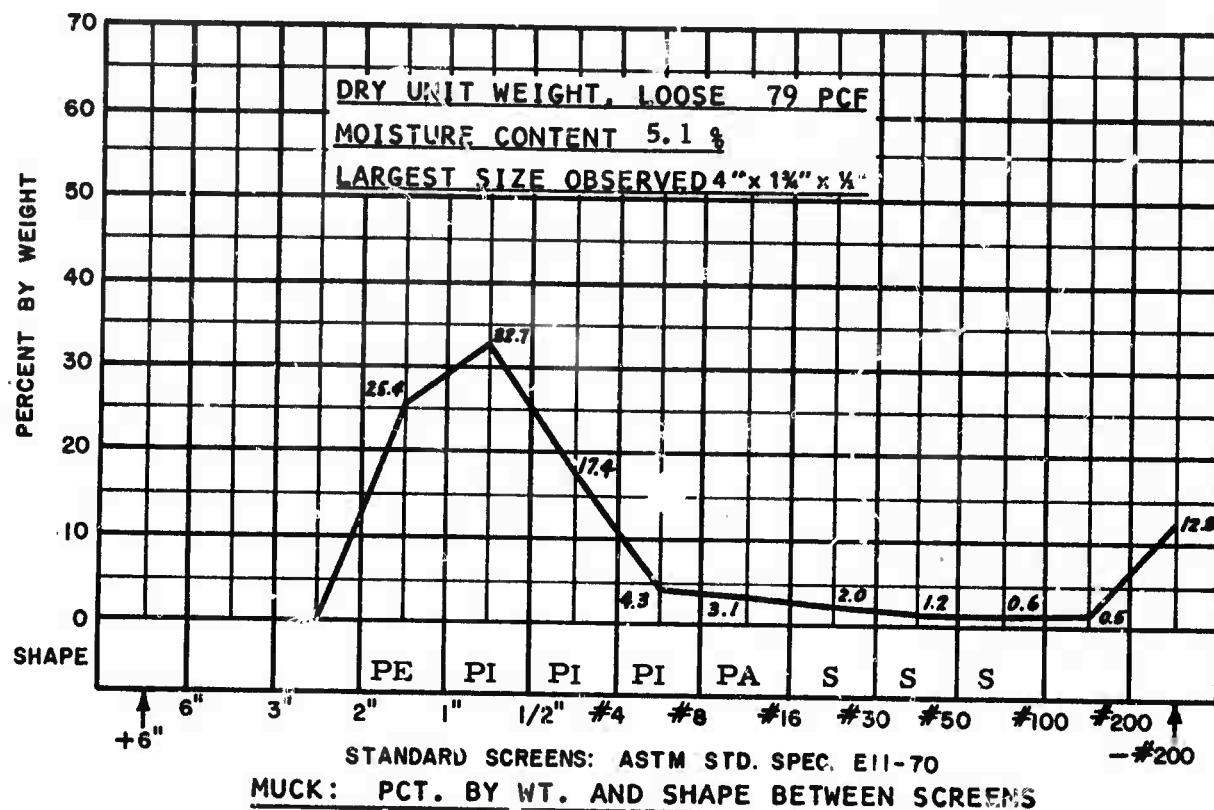
Shrinkage Limit 12.96 %
Flow Index 3.50 %

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop
@ 2.5 % Moisture, 36°
Angle Slide Steel Plate
@ 2.5 % Moisture, 32°

Apparent Cohesion PSF
@ 2.3 % Moisture, 60
Bulk Density PCF
@ 0.0 % Moisture, 95

Angle/Repose 10" Drop
@ 2.5 % Moisture, 32°
Angle Internal Friction
@ 2.3 % Moisture, 36°



SUMMARY

Rock Class: Sedimentary: Limestone, fine grained, horizontal jointing 4"-8".
High strength. RQD: 81%. DUW: 164 PCF. Ground water: Dry.
Hardness: NA.

System Class: TBM, Jarva 11-1100, 11'2" dia. 27 Reed disc cutters.
9.3 RPM, 119 K ft Torque, 639 K # Thrust. Mucking: Buckets to belt.
Haulage: Rail. Support: None.

MDN STUDY
9/1/72

SYSTEM DATA SHEET
MDN

Ident. No. MIL-3
Sheet 2

ROCK DATA:

Lithology: Sedimentary, limestone, light grey, fine grained.

Uniaxial Compressive Strength: 26K PSI.

RQD: 100%.

Dry Unit Weight: 168 PCF

Ground Water: Dry.

Hardness: NA.

TUNNEL DATA:

Size: 10' 4" diameter. Grade: (+) 0.2%.

Ventilation: 18 KCFM, exhaust, 30" diameter pipe, 90 HP @ 1980'.

Utility System: 3" water line.

Water Inflow: 300/400 gpm.

Power System: 7200/480V.

Haulage System: Muck, supplies, personnel by railcars, 5 ton locomotive,
4 CY cars, 24" gage, 54# rail.

Support System: None.

EXCAVATION DATA:

Machine: Robbins 105-144. Total weight: 75 tons.

Cutters: 26 Robbins, 12" and 11" discs. 2 Gage and 21 interior, 12" diameter,
3 center, 11" diameter.

Rotation: 6 RPM.

Torque: 280K ft. lb.

Thrust: 230K lb.

Muck Collection System: Buckets from face, belt to rear.

Power System: 4-100 HP motors drivehead, 50 HP for hydraulic system.

Guidance: Laser.

MUCK DATA

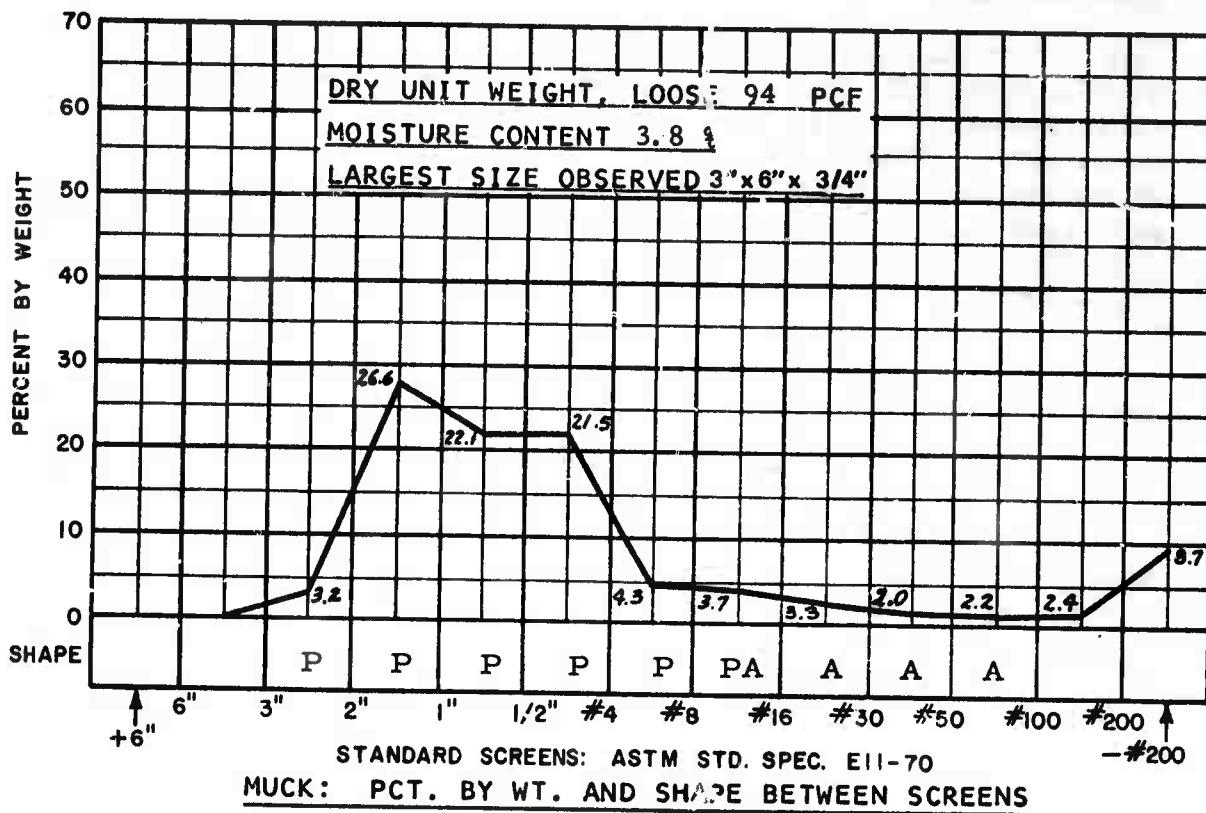
Abrasiveness Pot. Vol. Change, Material
 N. A. Size (-) 0.056": 0 Spec. Gravity, Material
 Size (-) 0.75": 2.81

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 15.10% Plastic Limit 13.69% Shrinkage Limit 11.57%
 Plasticity Index 1.41% Toughness Index 0.47% Flow Index 3.0 %

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop @ 3.1 % Moisture, 37°	Apparent Cohesion PSF @ 3.0 % Moisture, 70	Angle/Repose 10" Drop @ 3.1 % Moisture, 31°
Angle Slide Steel Plate @ 3.1 % Moisture, 31°	Bulk Density PCF @ 0.0 % Moisture, 104	Angle Internal Friction @ 3.0 % Moisture, 42°



SUMMARY

Rock Class: Sedimentary: Limestone fine grained. High strength.
 RQD 100%. DUW: 168 PCF. Ground water: Dry. Hardness, NA.

System Class: TBM, Robbins, 105-144, 10' 4" dia. 26 Robbins disc cutters.
 RPM: 6. 280 K ft # torque, 230 K # thrust. Mucking: Buckets tc belt.
 Haulage: Rail. Support: None.

MDN STUDY
 9/1/72

SYSTEM DATA SHEET
 MDN

Ident. No. EVG-1
 Sheet 2

ROCK DATA:

Lithology: Sedimentary, limestone, light grey, fine grained.

Uniaxial Compressive Strength: NA.

RQD: 100

Dry Unit Weight: NA.

Ground Water: Dry.

Hardness: NA.

TUNNEL DATA:

Size: 10' 4" diameter. Grade: (+) 0.2%.

Ventilation System: 18 KCFM, exhaust, 30" diameter pipe, 90 HP.

Utility System: 3" water line.

Water Inflow: 300/400 gpm.

Power System: 7200/480V.

Haulage System: Muck, supplies, personnel by railcars, 5 ton locomotive,
4 CY cars, 24" gage, 54# rail.

Support System: None.

EXCAVATION DATA:

Machine: Robbins 105-144. Total weight: 75 tons.

Cutters: 26 Robbins 12" and 11" discs, 2 gage and 21 interior-12" diameter
3 center-11" diameter.

Rotation: 6 RPM.

Torque: 246K ft. lb.

Thrust: 267K lb.

Muck Collection System: Buckets from face, belt to rear.

Power System: 4-100 HP motors drivehead, 50 HP for hydraulic system.

Guidance: Laser.

MUCK DATA

Abrasiveness
N. A.

Pot. Vol. Change, Material
Size : NA

Spec. Gravity, Material
Size : NA

ATTERBERG LIMITS, MATERIAL SIZE

Liquid Limit NA %
Plasticity Index NA %

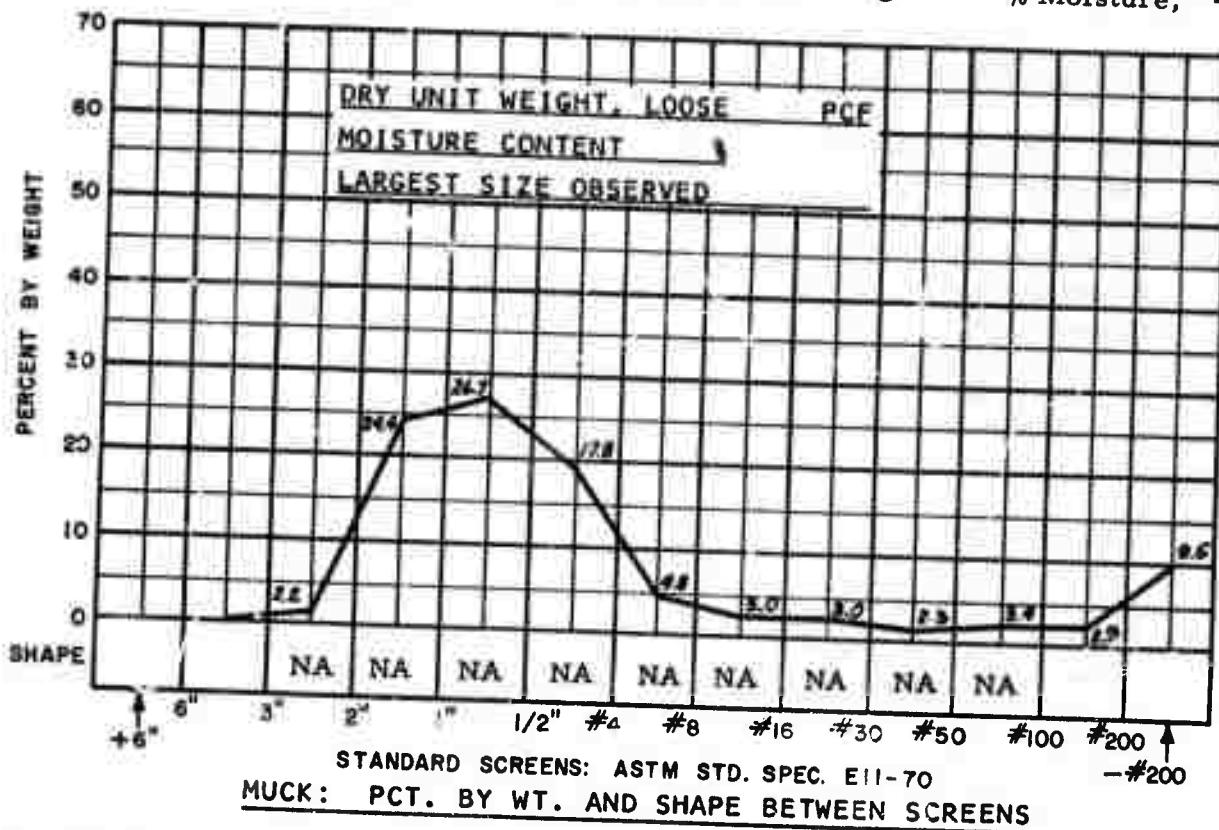
Plastic Limit NA %
Toughness Index NA %

Shrinkage Limit NA %
Flow Index NA %

MATERIAL SIZE IN.

Angle/Repose 1" Drop
@ % Moisture, NA @ % Moisture, NA
Angle Slide Steel Plate
@ % Moisture, NA @ % Moisture, NA

Angle/Repose 10" Drop
@ % Moisture, NA
Angle Internal Friction
@ % Moisture, NA



SUMMARY

Rock Class: Sedimentary: Limestone, fine grained. Strength: NA.
RQD: 100%. DUW: NA. Ground water: Dry. Hardness: NA.

System Class: TBM Robbins 105-144. 10'-4" dia. 26 Robbins disc cutters.
RPM: 6. Torque: 246 K ft #. Thrust: 267 K #. Mucking: Buckets to belt.
Haulage: Rail. Support: None.

MDN STUDY

9/1/72

SYSTEM DATA SHEET

MDN

Ident. No. EVG-2

Sheet 2

ROCK DATA:

Lithology: Sedimentary, sandstone, medium grained, light brown to red, massive, porous, poorly cemented.
Uniaxial Compressive Strength: 10 KPSI
RQD: (Estimated) 84%
Dry Unit Weight: 150 PCF
Ground Water: Generally dry.
Hardness: NA

TUNNEL DATA:

Size: 12'-11" diameter. Grade: (+).125%
Ventilation System: 15-17 KCFM exhaust, 36" dia. pipe, 100 HP @ 4100'.
Utility System: 3 1/2" water line, 6" air line, 8" pump line.
Water Inflow: 20-100 gpm.
Power System: 7300/480V
Haulage System: Muck, supplies, personnel, 10 ton locomotives, 10 CY cars, 24" gage, 65 lb. rail.
Support System: 4" H full rings, 4' centers: 35%; 13" x 9' pans 3/4" x 7' rock bolts: 10%.

EXCAVATION DATA:

Machine: Robbins 141-127, total weight: 125 tons.
Cutters: 32 Robbins steel disc. Gage: 6-12". Center: 1-11" triple disc. Interior: 23-11".
Rotation: Center cutter integral with head, 5.2 or 2.6 RPM.
Torque: 472 to 524 K ft. #.
Thrust: 331 K# to 382 K#. operating. Anchor pressure: 1,000 K#.
Muck Collection: Pickup by buckets fixed to head, discharging on 30" belt to a 24" x 204' belt on gantry.
Power System: 6-480/240V electric motors drive head. Hydraulic pumps power thrust and gripper cylinders.
Guidance System: Laser

MUCK DATA

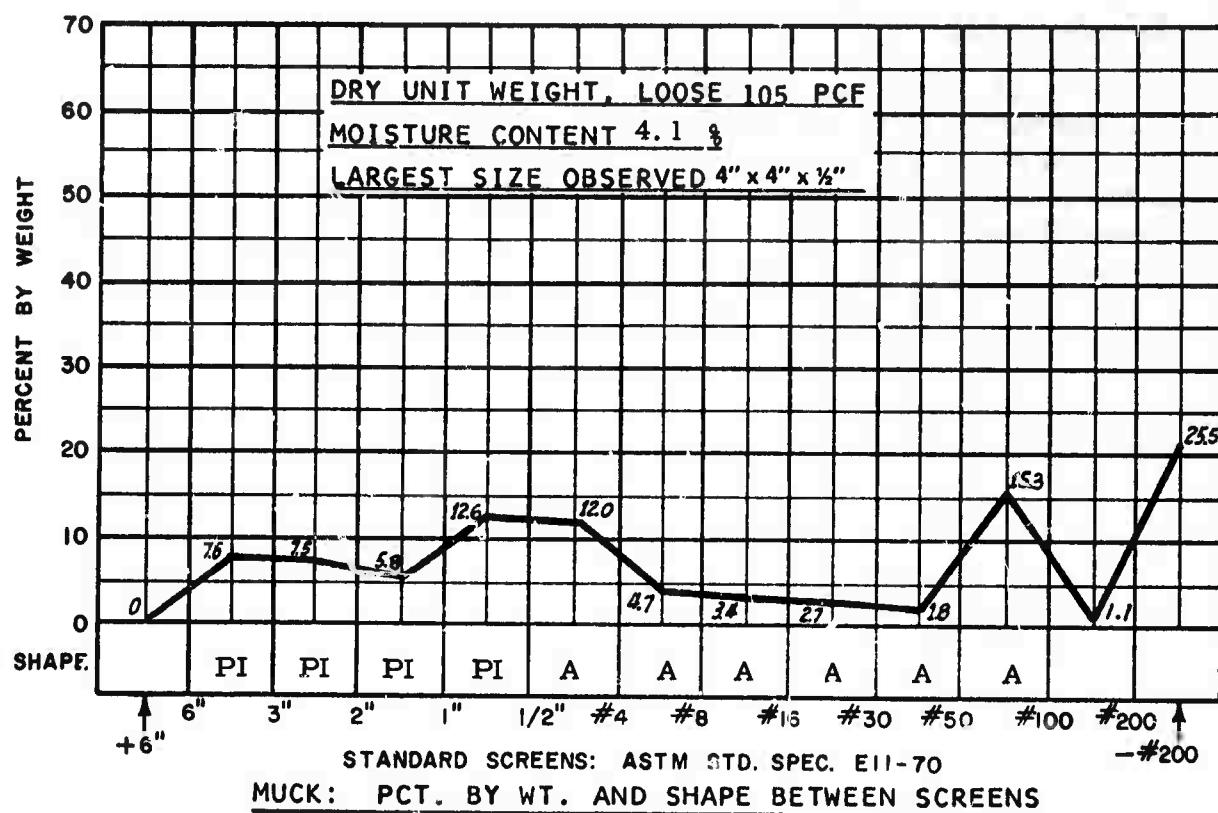
Abrasiveness Pot. Vol. Change, Material Spec. Gravity, Material
 N. A. Size (-) 0.056": 0 Size (-) 0.75": 2.66

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 21.20% Plastic Limit 17.06 % Shrinkage Limit 15.17 %
 Plasticity Index 3.14 % Toughness Index 0.52 % Flow Index 6.00 %

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop @ 3.6 % Moisture, 37°	Apparent Cohesion PSF @ 3.6 % Moisture, 210	Angle/Repose 10" Drop @ 3.6 % Moisture, 35°
Angle Slide Steel Plate @ 3.6 % Moisture, 27°	Bulk Density PCF @ 0.0 % Moisture, 97.4	Angle Internal Friction @ 3.6 % Moisture, 38°



SUMMARY

Rock Class: Sedimentary: Sandstone, medium grained, massive, porous, poorly cemented. Strength: Medium. RQD (Est.) 84%. DUW: 150 PCF.
Ground water: Dry. Hardness: NA.

System Class: TBM, Robbins 141-127, 12' 11" dia. 32 Robbins disc cutters.
 RPM: 5.2. Torque: 498 ft # av. Thrust: 357 K # av. Mucking: Buckets to belt conveyor. Haulage: Gantry conveyor to rail cars. Support: Steel ring sets, 35%, roof bars and rock bolts, 10% of 4100'.

MDN STUDY

9/1/72

SYSTEM DATA SHEET

MDN

Ident. No. LAY-1

Sheet 2

ROCK DATA:

Lithology: Sedimentary, conglomerate, well graded cobbles to pebbles of quartzite poorly to well cemented with reddish brown sandstone.
Uniaxial Compressive Strength: NA.
RQD: (Estimated) 85%.
Dry Unit Weight: NA.
Ground Water: Dry.
Hardness: NA.

TUNNEL DATA:

Size: 12' 11" diameter. Grade: (+) 0.125%.
Ventilation System: 15-17 KCFM, 36" diameter pipe, 100 HP
Utility System: 3 1/2" water line, 6" air line, 8" pump line.
Water Inflow: 20-100 gpm.
Power System: 7300/480V.
Haulage System: Muck, supplies, personnel by railcar 10 ton locomotive,
10 CY cars, 24" gage 65# rail.
Support System: 4" H full rings in bad ground.

EXCAVATION DATA:

Machine: Robbins 141-127. Total weight: 125 tons.
Cutters: 30 Robbins steel disc, gage 6-12", center 1-11" triple disc
interior 23-11".
Rotation: 5.2 RPM.
Torque: 490.7K ft. lb.
Thrust: 585.2K lb.
Muck Collection: Buckets from face, belt to rear.
Power System: 6-100 HP motors drivehead.
Guidance: Laser.

MUCK DATA

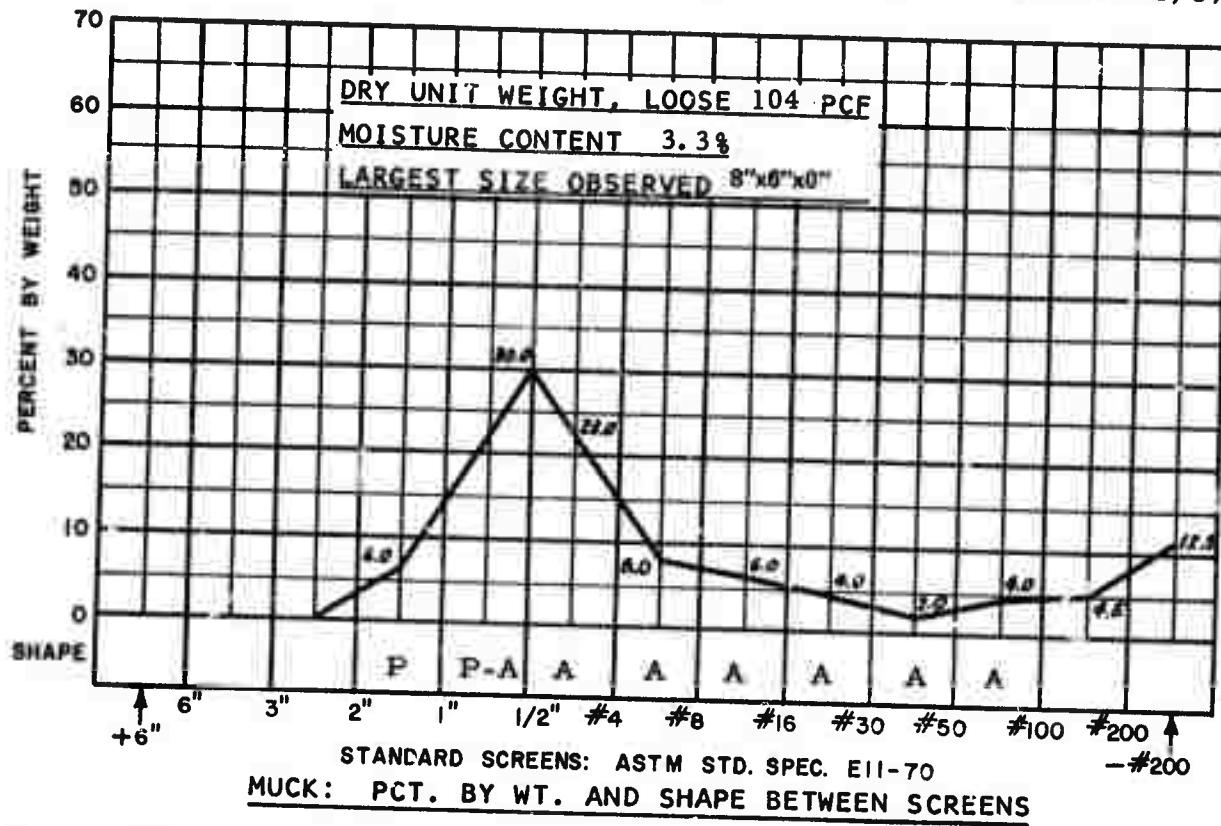
Abrasiveness **Pot. Vol. Change, Material** **Spec. Gravity, Material**
N. A. **Size (-) 0.056": 0** **Size (-) 0.75": 2.65**

ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 15.00% Plastic Limit 14.18 % Shrinkage Limit 13.80 %
Plasticity Index 0.82 % Toughness Index 0.21 % Flow Index 4.00 %

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop @ 3.4 % Moisture, 18°	Apparent Cohesion PSF @ 3.0 % Moisture, 15	Angle/Repose 10" Drop @ 3.4 % Moisture, 32°
Angle Slide Steel Plate @ 3.4 % Moisture, 32°	Bulk Density PCF @ 0.0 % Moisture, 88	Angle Internal Friction @ 3.0 % Moisture, 39°



SUMMARY

Rock Class: Sedimentary: Conglomerate, quartzite cobbles grading to pebbles, poorly to well cemented with sandstone. Strength: NA: RQD (Est.) 85%. DUW: NA. Ground water: Dry. Hardness: NA.

System Class: TB^M Robbins 141-127. 32 Robbins disc cutters. RPM: 5.2
Torque: 491 K ft #. Thrust: 585 K #. Mucking: Buckets to belt.
Haulage: Rail. Support: Rock bolts, normal, ring sets in bad ground.

MDN STUDY

9/1/72

SYSTEM DATA SHEET

MDN

Ident. No. LAY-2
Sheet 2

ROCK DATA:

Lithology: Sedimentary, siltstone, fine grained, gray, more than 33% quartz, 30% clay, 10% feldspar, 15% mica, chlorite and gypsum.
Uniaxial Compressive Strength: 2 KPSI
RQD: (Estimated) 70%
Dry Unit Weight: 142 PCF
Ground Water: Table above tunnel but sealed off by overlying beds.
Hardness: NA

TUNNEL DATA:

Size: 20.5' round, Grade: (+) .05%
Ventilation System: 18 KCFM exhaust 30" pipe, 60 HP.
Utility System: 6" air line, 4" pump line
Water Inflow: 50 GPH.
Power System: 4160/440V, rectified to 440 DC for head drive motors.
Haulage System: Muck, supplies, personnel, by 16 CY cars, 15 ton motor, 24" gage 70 lb rail.
Support System: Rock bolts, 8' and 10' x 3/4", set in epoxy with 5' and 13' x 16 gage pans, shotcrete placed to prevent air slacking.

EXCAVATION DATA:

Machine: Dresser TB-205, total weight: 200 tons
Cutters: 36 Dresser steel and TCB insert discs, 32 Kennametal U43 and U44 "pick" bits. Gage: 6-#9T5TD1 TCB insert discs. Center: 6-U43TC bits mounted around a 4" chisel. Interior: 30 Type STD steel discs and 26 U44 TC bits mounted on 4 bit blocks.
Rotation: 0-6 RPM range, 5 RPM normal operating.
Torque: Maximum 879 K ft. #, normal operating 586 K ft. #.
Thrust: Maximum 1,583 K # operating 431 K #.
Anchor Pressure: Maximum 6,616 K#.
Muck Collection: Buckets from face to 36" belt to 36" belt on 140' gantry.
Power System: Four 180 HP D.C. head motors, one 75 HP for hydraulic system.
Guidance System: Laser

MUCK DATA

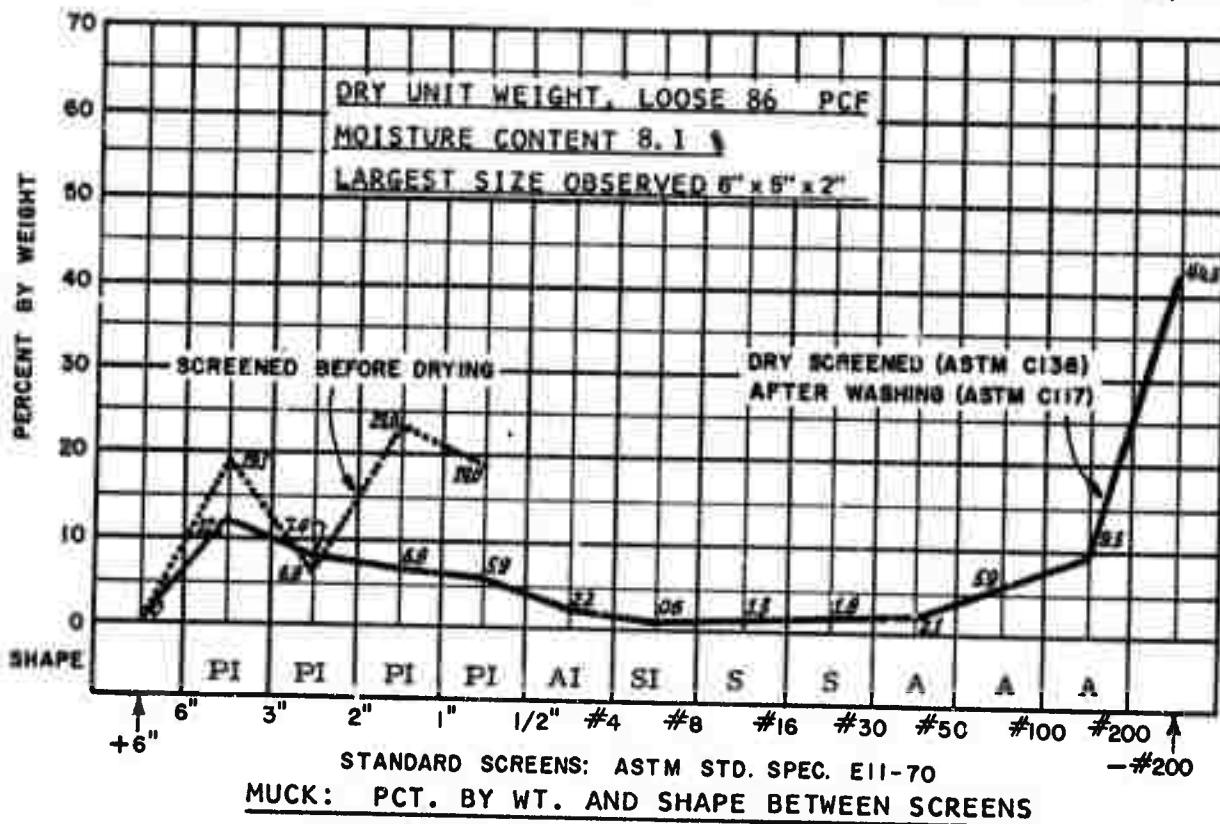
Abrasiveness N. A. Pot. Vol. Change, Material Size (-)0.056": 1.3 Spec. Gravity, Material Size (-)0.75": 3.13

ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 36.80% Plastic Limit 23.61% Shrinkage Limit 21.04%
Plasticity Index 13.1% Toughness Index 1.88% Flow Index 7.00%

MATERIAL SIZE (-)2.0 IN.

Angle/Repose 1" Drop @ 7.7 % Moisture, 30°	Apparent Cohesion PSF @ 7.5 % Moisture, 340	Angle/Repose 10" Drop @ 7.7 % Moisture, 30°
Angle Slide Steel Plate @ 7.7 % Moisture, 30°	Bulk Density PCF @ 0.0 % Moisture, 98	Angle Internal Friction @ 7.5 % Moisture, 36°



SUMMARY

Rock Class: Sedimentary: Siltstone, fine grained. Strength: Very low.
RQD (Est.) 70%. DUW: 142 PCF. Ground water: Minor. Hardness: NA.

System Class: TBM, Dresser TB 205, 20.5' dia., Dresser disc cutters: 6TCB and 30 steel, 32 Kennametal, TCB "pick" bits. RPM: 5, 586 K ft #. Torque: 431 K # thrust. Mucking: Buckets to belt. Haulage: Rail. Support: Roof plates and rock bolts, at 3' or 4', continuous.

MDN STUDY

9/1/72

SYSTEM DATA SHEET

MDN

Ident. No. NAV-1

Sheet 2

ROCK DATA:

Lithology: Sedimentary, sandstone, gray, medium grained, massive, friable and porous. Grains angular to subrounded, primarily quartz, poorly cemented.

Uniaxial Compressive Strength: Less than 1 KPSI, disintegrates when wet.

RQD: (Estimated) 60%

Dry Unit Weight: 117 PCF

Ground Water: Table above tunnel but sealed off by overlying beds.

Hardness: NA

TUNNEL DATA:

Size: 20.5' diameter. Grade: (+) .05%

Ventilation System: 18 KCFM exhaust, 30" pipe, 60 HP.

Utility System: 6" air line, 4" pump line

Water Inflow: 50 GPH.

Power System: 4160/440V, rectified to 440 DC for head drive motors.

Haulage System: Muck, supplies, personnel, by 16 CY cars, 15 ton motor, 24" gage 70 lb rail.

Support System: Rock bolts, 8' and 10' x 3/4", set in epoxy, with 5' and 13' x 16 gage pans, shotcrete placed to prevent air slacking.

EXCAVATION DATA:

Machine: Dresser TB-205, total weight: 200 tons

Cutters: 36 Dresser steel and TCB insert discs, 32 Kennametal U43 and U44 "pick" bits. Gage: 6-#9T5TD1 TCB insert discs. Center: 6-U43TC bits mounted around a 4" chisel. Interior: 30 Type STD steel discs and 26 U44TC bits mounted on 4 bit blocks.

Rotation: 0-6 RPM range, 5 RPM normal operating.

Torque: Maximum 879 K ft. #., normal operating 586 K ft. #.

Thrust: Maximum 1,583 K #. operating 123 K #.

Anchor Pressure: Maximum 6,616 K #.

Muck Collection: Buckets from face to 36" belt to 36" belt on 140' gantry.

Power System: Four 180 HP D.C. head motors, one 75 HP for hydraulic system.

Guidance System: Laser

MUCK DATA

Abrasiveness
N. A.

Pot. Vol. Change, Material
Size (-) 0.056": 0

Spec. Gravity, Material
Size (-) 0.75": 2.72

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 18.20%
Plasticity Index 1.29 %

Plastic Limit 16.91%
Toughness Index 0.28 %

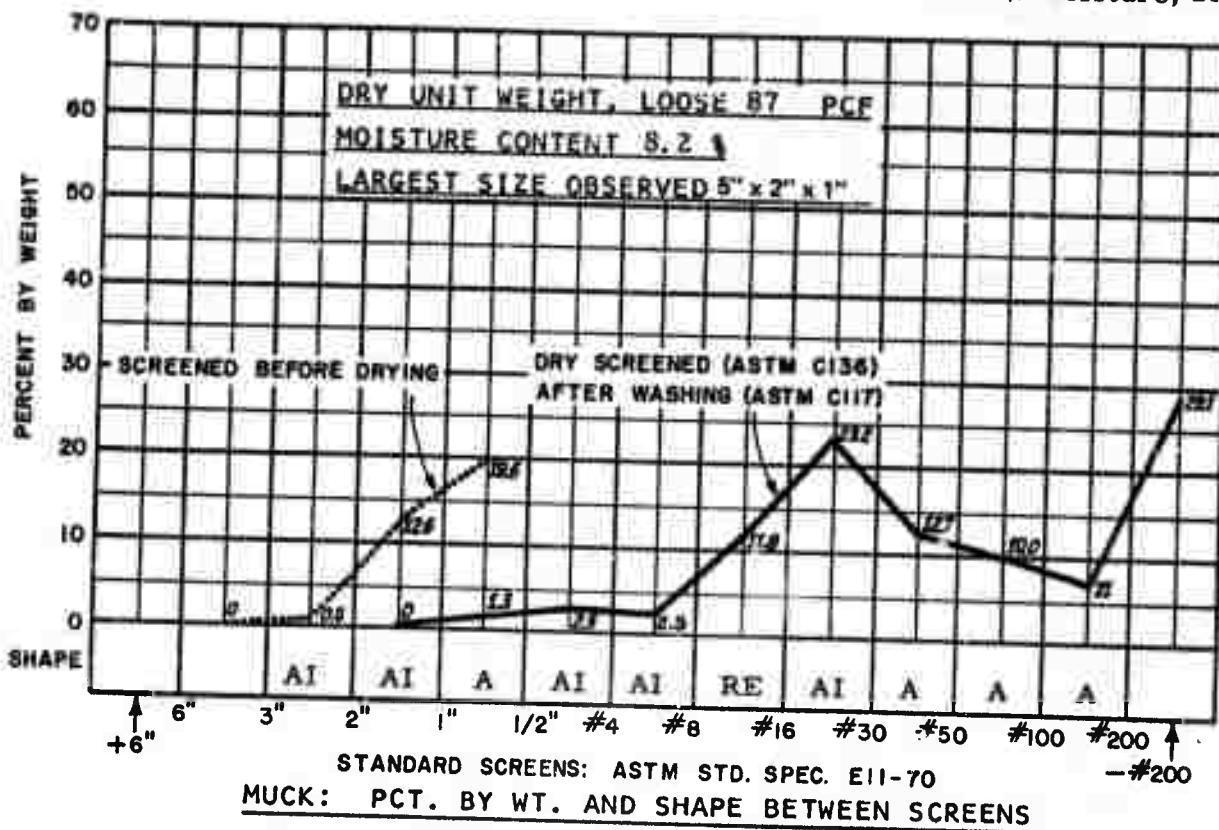
Shrinkage Limit 16.60 %
Flow Index 4.50 %

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop
@ 8.6 % Moisture, 31°
Angle Slide Steel Plate
@ 8.6 % Moisture, 32°

Apparent Cohesion PSF
@ 8.1 % Moisture, 45
Bulk Density PCF
@ 0.0 % Moisture, 99

Angle/Repose 10" Drop
@ 8.6 % Moisture, 28°
Angle Internal Friction
@ 8.1 % Moisture, 28°



SUMMARY

Rock Class: Sedimentary: Sandstone, massive, friable, porous, medium grained. Very low strength. RQD (Est.) 60%. DUW: 117 PCF. Ground water: Minor. Hardness: NA.

System Class: TBM, Dresser TB 205, 20.5' dia. Dresser, disc cutters 6TCB and 30 steel, 32 Kennametal, TCB "pick" bits. RPM: 5, 586 K ft # torque, 123 K # thrust. Mucking: Buckets to belt. Haulage: Rail. Support: Roof plates and rock bolts, at 3' or 4', continuous.

MDN STUDY

1/1/72

SYSTEM DATA SHEET
MDN

Ident. No. NAV-2
Sheet 2

ROCK DATA:

Lithology: Sedimentary, sandstone, fine grained, brown to dark red massive.
Uniaxial Compressive Strength: NA.
RQD: 60%.
Dry Unit Weight: NA.
Ground Water: Generally dry.
Hardness: NA.

TUNNEL DATA:

Size: 18' 4" diameter. Grade: +.045%.
Ventilation System: 22 KCFM, exhaust, 48" diameter pipe, 2-150 HP
Utility System: 8" air line, 4" water line, 8" pump line.
Water Inflow: 40 gpm.
Power System: 13200/440V.
Haulage System: Muck, supplies, personnel by railcars, 15 ton locomotive
10 CY cars, 36" gage, 50# rail.
Support System: Rock bolts, 5', 6', 8' x 5/8", 24" centers, 14 gauge pans
12' 6" or 8' 6" x 8".

EXCAVATION DATA:

Machine: Lawrence HRT. Total weight: NA.
Cutters: 32 Lawrence Mfg Tungsten Carbide Button, roller, disc and tricone.
Gage: 5 TCB roller, Interior 24 disc and 2 TCB roller, center 1-24"
TCB tricone.
Rotation: Head 11 RPM, center 30 RPM.
Torque: Center cutter 150 HP, head 750 HP, 364K ft. lb.
Thrust: 492K lbs.
Muck Collection: Buckets from face discharging to 24" belt.
Power System: Electro-Hydraulic. Total HP: 960
Guidance System: Laser

MUCK DATA

Abrasiveness N. A. Pot. Vol. Change, Material Size NA : Spec. Gravity, Material Size NA :

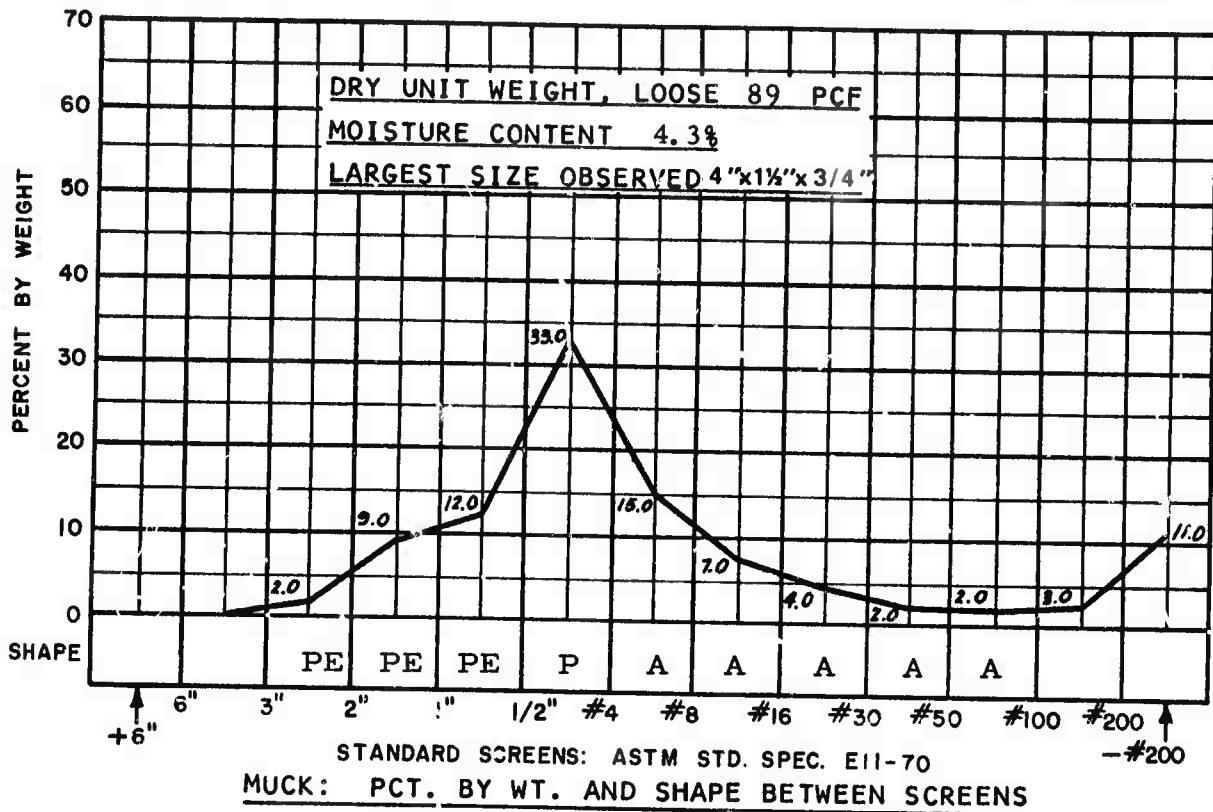
ATTERBERG LIMITS, MATERIAL SIZE

IN.

Liquid Limit NA % Plastic Limit NA % Shrinkage Limit NA %
Plasticity Index NA % Toughness Index NA % Flow Index NA %

MATERIAL SIZE IN.

Angle/Repose 1" Drop @ % Moisture, NA	Apparent Cohesion PSF @ % Moisture, NA	Angle/Repose 10" Drop @ % Moisture, NA
Angle Slide Steel Plate @ % Moisture, NA	Bulk Density PCF @ % Moisture, NA	Angle Internal Friction @ % Moisture, NA



SUMMARY

Rock Class: Sedimentary: Sandstone, fine grained, massive. Strength: NA.
 RQD: 60%. DUW: NA. Ground water: Dry. Hardness: 32, schmidt.

System Class: TBM Lawrence HRT 18' 4" dia. 32 Lawrence button roller, disc cutters. 11 RPM head, 30 RPM center. 364 K ft # torque. 492 K # thrust.
 Mucking: Buckets to belt. Haulage: Rail. Support: Rock bolts 24" centers.

MDN STUDY

9/1/72

SYSTEM DATA SHEET
 MDN

Ident. No. RO-1

Sheet 2

ROCK DATA:

Lithology: Sedimentary, sandstone, coarse grained, poorly consolidated, arkosic, with minor layers of thin seamed siltstone.

Uniaxial Compressive Strength: 50 to 150 PSI dry-disintegrates when wet.

RQD: (Estimated) 30%.

Dry Unit Weight: 125 PCF.

Ground Water: Saturated when first opened.

Hardness: NA

TUNNEL DATA:

Size: 10' high by 8' wide, rectangular. Grade (+) 1/2%.

Ventilation System: 5 to 7 KCFM, pressure, 18" dia. vent tube.

Utility System: 4" airline.

Water Inflow: 20-25 gpm.

Power System: 440/110V, trailing cable.

Haulage System: Muck, personnel and supplies by rail cars, 24" gage, 40# rail.

Support System: None, rock bolts and/or shotcrete in bad ground.

EXCAVATION DATA:

Machine: Alpine Miner, Type F6-A. Total Weight: 11 tons.

Cutters: 72, Kennametal U43K, Carbide tipped, "pick" type. Cutters, mounted on twin ripper heads, rotating about a horizontal axis at 90° to a boom which moves the heads vertically and horizontally.

Rotation: 60 RPM, motor and gear box integral with boom.

Torque: 50.4 HP

Thrust: Sumping thrust from crawler motors, 2 @ 20.4 HP. Vertical and horizontal by hydraulic cylinders powered by a 10.4 HP electro-hydraulic system.

Anchor Pressure: Crawlers only.

Muck Collection: Central 14" chain conveyor, fed by gathering arms, discharges on an 18" x 30' belt feeding 116' of 20" Serpentix conveyor. Transverse folds are molded into 20" x 8" long rubber Serpentix sections, which are bolt connected at reinforced flanges connected to an endless chain driven by a sprocket. Folds allow inside edge to compress and outside to expand on curves. Vertebral side rail sections, alternating with straight sections, are supported by wheeled gantry legs riding a 60" gage track, under which cars are spotted.

Power System: 440V, trailing cable.

Guidance System: Transit/Laser.

MDN STUDY
9/1/72

SYSTEM DATA SHEET
MDN

Ident. No. WNG-1
Sheet 1

MUCK DATA

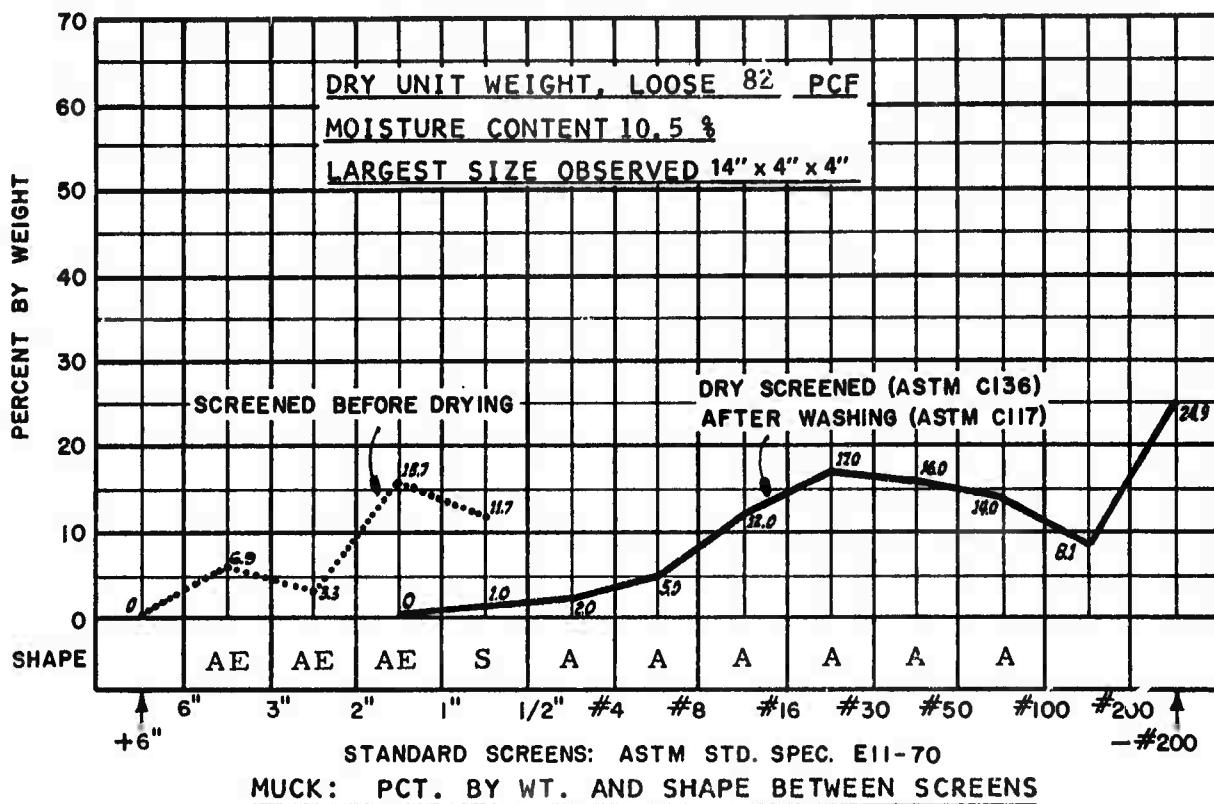
Abrasiveness N. A. Pot. Vol. Change, Material Size (-) 0.056": 0 Spec. Gravity, Material Size (-) 0.75": 2.71

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 24.90% Plastic Limit 19.97% Shrinkage Limit 19.94%
Plasticity Index 4.93% Toughness Index 0.66% Flow Index 7.40%

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop @ 10.1 % Moisture, 34°	Apparent Cohesion PSF @ 10.6 % Moisture, 0	Angle/Repose 10" Drop @ 10.1 % Moisture, 31°
Angle Slide Steel Plate @ 10.0 % Moisture, 32°	Bulk Density PCF @ 0.0 % Moisture, 85	Angle Internal Friction @ 10.6 % Moisture, 27°



SUMMARY

Rock Class: Sedimentary: Sandstone, coarse grained, poorly consolidated, arkosic, minor thin seamed siltstone. Very low strength. RQD (Est.) 30%. DUW: 125 PCF. Ground water: Saturated. Hardness: NA.

System Class: TBM, Alpine F6A, twin head, 10' high x 8' heading. 72 Kennametal TCB pick type bits. 60 RPM, 50.4 HP head torque, 10.4 HP boom power, 40.8 HP sumping thrust. Mucking: Gathering arms-flight conveyor. Haulage: Elevating conveyor - Serpentix conveyor on gantry - rail cars. Support: Normally none.

MDN STUDY

9/1/72

SYSTEM DATA SHEET

MDN

Ident. No. WNG-1

Sheet 2

ROCK DATA:

Lithology: Sedimentary, sandstone, coarse grained, poorly consolidated, arkosic, with minor layers of thin seamed siltstone, varying concentrations of replacement silica.

Uniaxial Compressive Strength: 50 to 150 PSI dry-disintegrates when wet.

RQD: (Estimated) 30%

Dry Unit Weight: 125 PCF

Ground Water: Saturated when first opened.

Hardness: NA

TUNNEL DATA:

Size: 5' wide x 9' high, nominally rectangular. Grade: Varies.

Ventilation System: 5 to 7 KCFM, pressure, 18" vent tube.

Utility System: 2" air, 1" waterline.

Water Inflow: 20-25 gpm when levels are first opened; generally dry after drainage.

Power System: None in development headings, 440V to scraper hoists, 110V lighting.

Haulage System: Muck is scraped from the face of a cross cut to a slusher drift, cross scraped to a muck raise, and loaded into 4 cu. ft. rocker dump rail cars on main level about 80' below. Scrapers are 42", hoists 15 HP. Personnel access by ladder, supplies by rail cars and air-powered hoists through raises.

Support System: None. Rockbolts in bad ground.

EXCAVATION DATA:

Conventional Scraper-Rail Haulage System.

Drilling: LeRoi Model 35 jackhammers mounted on 6' airfeed legs.

Drill Round: Five hole box or vertical line burn cut, 6' depth, included in 18 hole round, all holes 1 1/2" diameter.

Explosives: 50# Dupont 40% Gelex #2, Powder factor: 5#/cu. yd.

Blasting: Safety fuse and caps.

Mucking System: 42" Scrapers, 15 HP hoists.

MUCK DATA

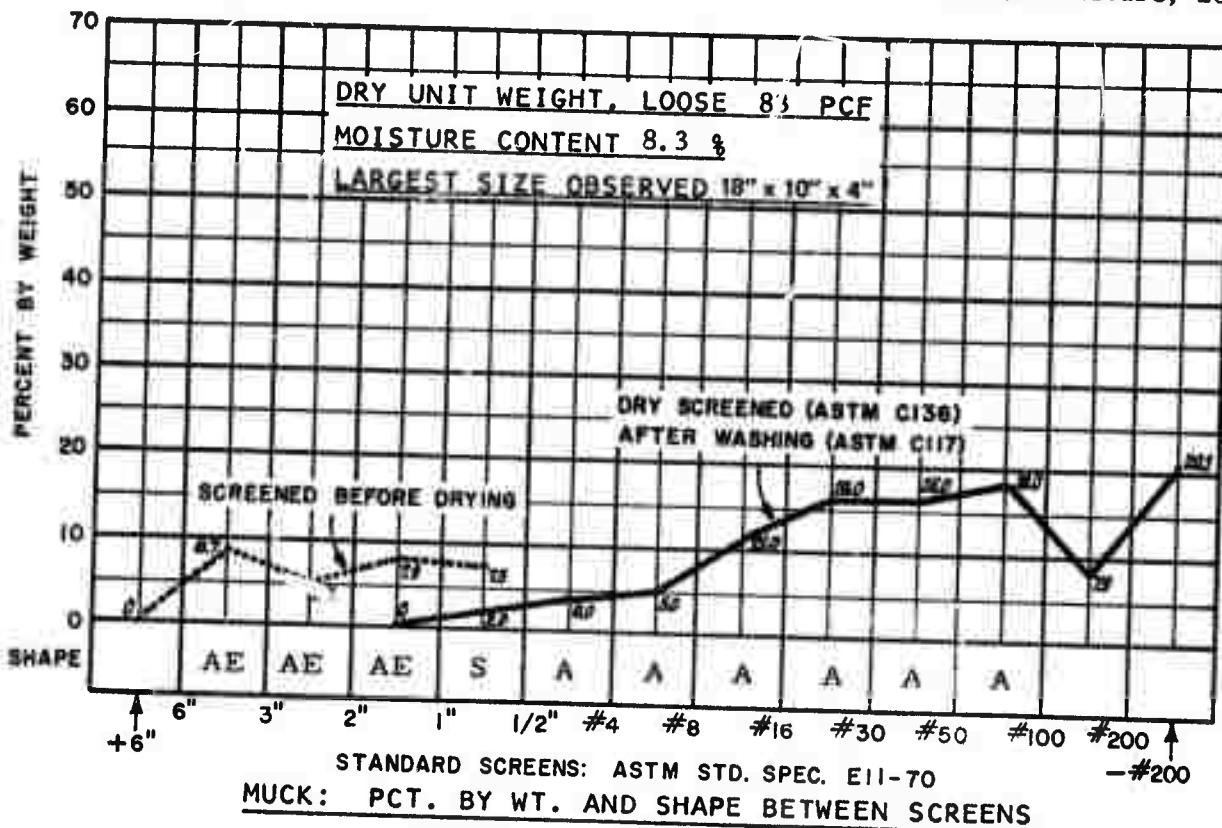
Abrasiveness **Pot. Vol. Change, Material** **Spec. Gravity, Material**
N. A. **Size (-) 0.056": 0** **Size (-) 0.075": 2.72**

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 25.25% Plastic Limit 24.74% Shrinkage Limit 23.37%
 Plasticity Index 0.51% Toughness Index 0.13% Flow Index 4.00%

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop @ 9.0 % Moisture, 32°	Apparent Cohesion PSF @ 9.0 % Moisture, 0	Angle/Repose 10" Drop @ 9.0% Moisture, 31°
Angle Slide Steel Plate @ 9.0 % Moisture, 40°	Bulk Density PCF @ 0.0 % Moisture, 86	Angle Internal Friction @ 9.0 % Moisture, 28°



SUMMARY

Rock Class: Sedimentary: Sandstone, coarse grained, poorly consolidated, arkosic, minor thin seamed siltstone, varying replacement silica. Very low strength. RQD (Est.) 30%. DUW: 125 PCF. Ground water: Saturated.
Hardness: NA.

System Class: Conventional Scraper-Rail. 5' wide x 9' high, rectangular. Airleg jackhammer, 18 - 6' holes, burn cut. PF 5#/CY. Mucking: Scraper to raise. Haulage: Rail cars - skip to surface. Support: Normally none.

MDN STUDY
9/1/72

SYSTEM DATA SHEET

MDN

Ident. No. WNG-2
Sheet 2

ROCK DATA:

Lithology: Sedimentary, sandstone, arkosic, irregularly bedded, loosely consolidated with layers and lenses of silty mudstone.

Uniaxial Compressive Strength: Less than one KPSI.

RQD: (Estimated) 15%

Dry Unit Weight: 113 PCF

Ground Water: Saturated; water table above tunnel, heading is drained in advanced by lateral pilot holes in ribs.

Hardness: NA

TUNNEL DATA:

Size: 21 ft., diameter. Grade: (+) 0.2%.

Ventilation System: 20 KCFM, 36" pipe, pressure at face, exhaust in access.

Utility System: 6" air line, 6" pump line.

Water Inflow: 200 gpm.

Power System: 4160/480V.

Haulage System: Muck, personnel, supplies by rail cars.

Support System: Continuous, precast concrete rings 8" and 10" thick, erected in four-4' segments.

EXCAVATION DATA:

Shield: Robbins 221S ripper, Total weight: 285 tons

Thrust: 3,500 tons total.

Muck Collection System: Muck is ripped from the face by a ripper tooth and drawn through the shield to a 6' conveyor by hydraulic ram with a bucket opposite the ripper tooth.

Power System: Hydraulic.

Guidance System: Laser

MUCK DATA

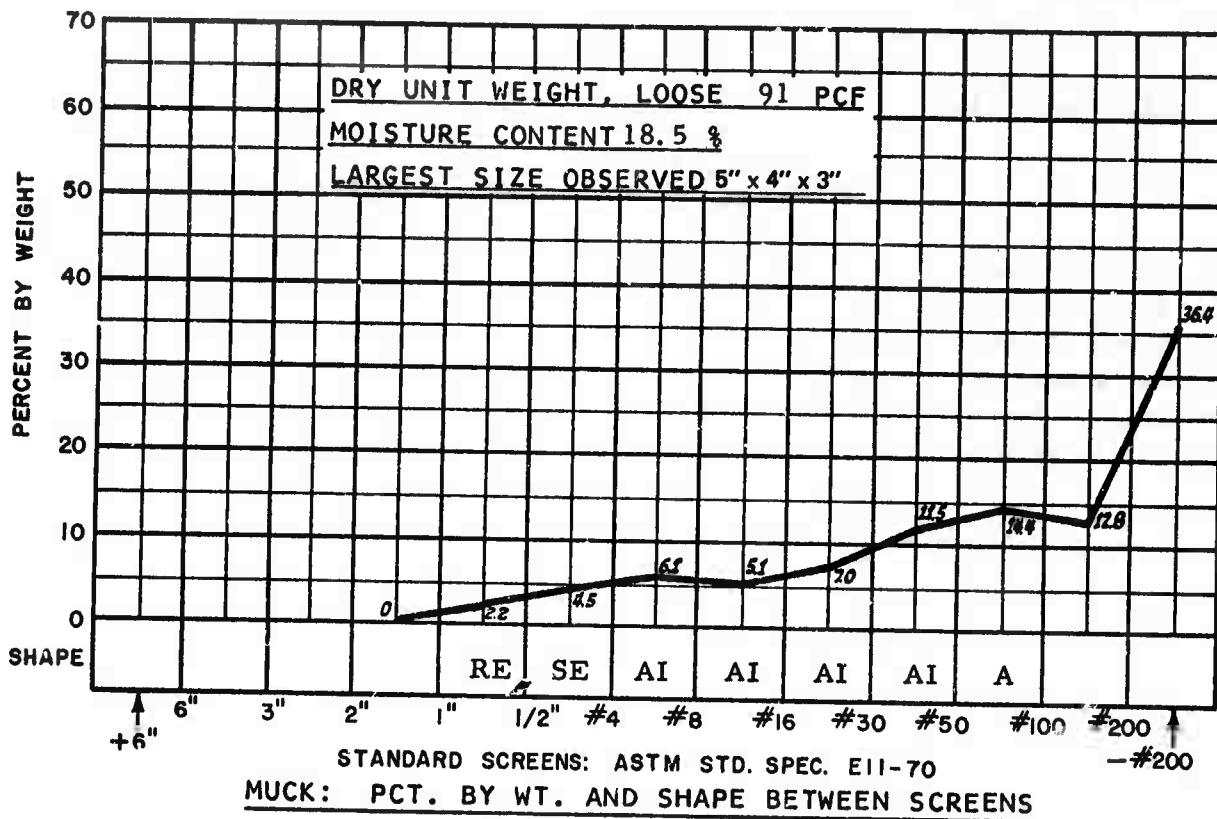
Abrasiveness N. A. Pot. Vol. Change, Material Size (-)0.065" : 0 Spec. Gravity, Material Size (-)0.185": 2.86

ATTERBERG LIMITS, MATERIAL SIZE (-)0.185 IN.

Liquid Limit 17.75% Plastic Limit 16.19% Shrinkage Limit 13.94%
Plasticity Index 1.56 % Toughness Index 0.27 % Flow Index 5.8 %

MATERIAL SIZE (-)0.185IN.

Angle/Repose 1" Drop @ 14.3 % Moisture, 38°	Apparent Cohesion PSF @ % Moisture, NA	Angle/Repose 10" Drop @ 14.3 % Moisture, 33°
Angle Slide Steel Plate @ 12.5 % Moisture, 36°	Bulk Density PCF @ % Moisture, NA	Angle Internal Friction @ 13.0 % Moisture, 42°



SUMMARY

Rock Class: Sedimentary: Sandstone, arkosic, loosely consolidated, with layers and lenses of silty mudstone. Strength: Very low. RQD (Est.) 15%. DUW: 113 PCF. Ground water: Saturated. Hardness: NA.

System Class: Shield, Robbins 221S ripper, 21' dia. Thrust: 3500 tons. Mucking: Hydraulic boom operated bucket scraper to conveyor. Haulage: Rail. Support: Continuous, precast concrete ring segments.

MDN STUDY

9/1/72

SYSTEM DATA SHEET

MDN

Ident. No. SF-1

Sheet 2

ROCK DATA:

Lithology: Sedimentary, sandstone, biotite rich siltstone,
poorly to well consolidated, poorly to well sorted.

Uniaxial Compressive Strength: 2 KPSI

RQD: (Estimated) 50%

Dry Unit Weight: 142 PCF

Ground Water: Sandstone saturated, water table above tunnel, heading
drained in advanced by lateral pilot holes in ribs.

Hardness: NA

TUNNEL DATA:

Size: 21 ft., round, Grade: (+) 0.2 pct.

Ventilation System: 20 KCFM, 36" pipe, pressure at face, exhaust in
access.

Utility System: 6" air line, 6" pump line.

Water Inflow: 20 gpm

Power System: 4160/480V

Haulage System: Muck, personnel, supplies by rail cars.

Support System: Continuous, precast concrete rings 8" and 10" thick,
erected in four 4' segments.

EXCAVATION DATA:

Shield: Robbins 221S ripper, total weight: 285 tons.

Thrust: 3,500 tons total.

Muck Collection System: Muck is ripped from face by a ripper tooth and
drawn through the shield to a 6' conveyor by hydraulic ram with a bucket
opposite the ripper tooth.

Power System: Hydraulic

Guidance System: Laser

MUCK DATA

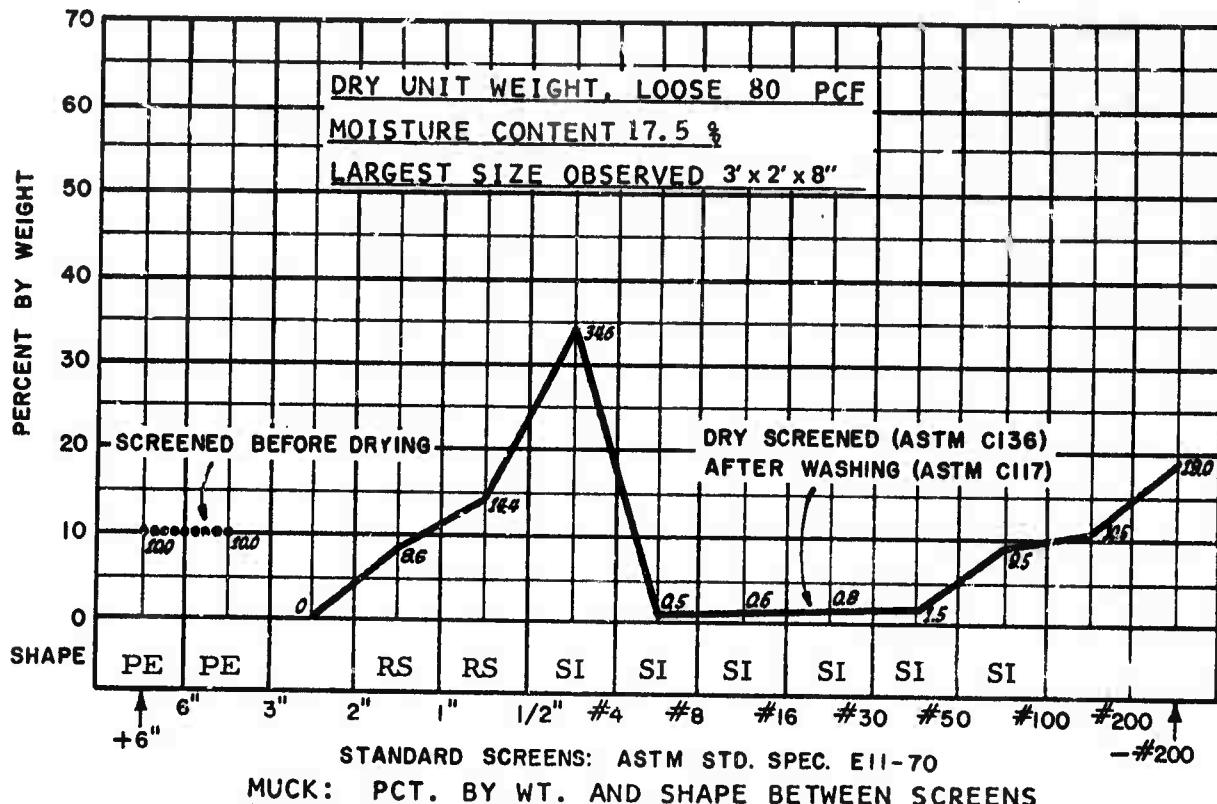
Abrasiveness N. A. Pot. Vol. Change, Material Size (-)0.056": 0 Spec. Gravity, Material Size (-)0.075": 3.02

ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 31.5 % Plastic Limit 26.8 % Shrinkage Limit 21.5 %
Plasticity Index 4.7 % Toughness Index 0.61 % Flow Index 7.6 %

MATERIAL SIZE (-)1.0 IN.

Angle/Repose 1" Drop @ 15.1 % Moisture, 38°	Apparent Cohesion PSF @ % Moisture, NA	Angle/Repose 10" Drop @ 15.1 % Moisture, 36°
Angle Slide Steel Plate @ 15.1 % Moisture, 30°	Bulk Density PCF @ % Moisture, NA	Angle Internal Friction @ 15 % Moisture, 27°



SUMMARY

Rock Class: Sedimentary: Sandstone and siltstone, poorly to well consolidated. Strength: Very low. RQD (Est.) 50%. DUW: 142 PCF.
Ground water: Saturated. Hardness: NA.

System Class: Shield, Robbins 221S ripper, 21' dia. Thrust 3500 tons.
Mucking: Hydraulic boom operated bucket scraper to conveyor.
Support: Continuous, precast concrete ring segments.

MDN STUDY
9/1/72

SYSTEM DATA SHEET
MDN

Ident. No. SF-2
Sheet 2

ROCK DATA:

Lithology: Sedimentary, mudstone, dark gray, fine grained, massive.

Uniaxial Compressive Strength: 11 KPSI dry.

RQD: (Estimated) 90%.

Dry Unit Weight: 144 PCF.

Ground Water: Generally dry.

Hardness: NA

TUNNEL DATA:

Size: 10' high x 9' wide (7'-6" top, 9'-6" bottom). Grade: (+) 1/2%.

Ventilation System: 5 KCFM, exhaust from face, pressure to venthole,
16" flexhaust, 24" vent tube, 2-25 HP Axivane fans.

Power System: 440V trailing cable.

Haulage System: Muck, personnel and supplies by rail cars, 36" gage,
45# rail.

Support: 4" WF steel sets at 3' or 6'.

EXCAVATION DATA:

Machine: Alpine Miner, Type F6-A. Total Weight: 11 tons.

Cutters: 40 Kennametal U43KH, Carbide tipped, "pick" type. Cutters
mounted on twin ripper heads, rotating about a horizontal axis at 90° to
a boom which moves heads vertically and horizontally.

Rotation: 78 RPM, motor and gear box integral with boom.

Torque: 50.4 HP.

Thrust: Sumping thrust from crawler motors, 2 @ 20.4 HP, vertical and
horizontal by hydraulic cylinders powered by a 10.4 HP electro-hydraulic
system.

Anchor Pressure: Crawlers only.

Muck Collection: Central 14" flight conveyor fed by two gathering arms
mounted on an inclined apron, discharges on an 18" elevating conveyor
loading rail cars.

Power System: 440V, trailing cable.

Guidance System: Transit/Laser.

MUCK DATA

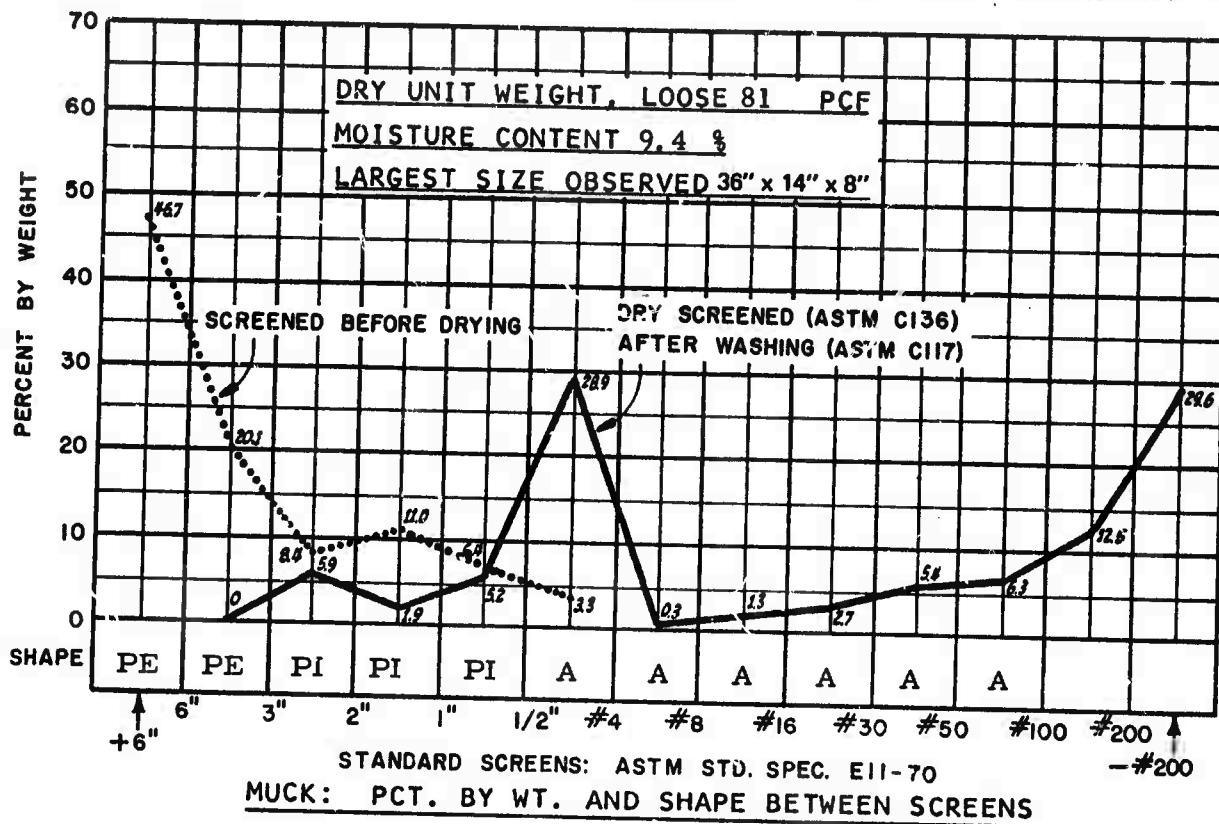
Abrasiveness N. A. Pot. Vol. Change, Material Size (-) 0.056": 0 Spec. Gravity, Material Size (-) 0.75": 2.87

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 28.30% Plastic Limit 24.97% Shrinkage Limit 19.12%
Plasticity Index 3.33% Toughness Index 0.92% Flow Index 3.60%

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop @ 12.7 % Moisture, 29°	Apparent Cohesion PSF @ 10.9 % Moisture, 37	Angle/Repose 10" Drop @ 12.7 % Moisture, 28°
Angle Slide Steel Plate @ 12.7 % Moisture, 31°	Bulk Density PCF @ 0.0 % Moisture, 79	Angle Internal Friction @ 10.9 % Moisture, 35°



SUMMARY

Rock Class: Sedimentary: Mudstone ("shale") fine grained, massive.
Medium strength. RQD (Est.) 90%. DUW: 144 PCF. Ground water: Dry.
Hardness: NA

System Class: TBM, Alpine F6A, twin head, 10' high x 9' heading. 40 Kernametal TCB pick type bits. 78 RPM, 50.4 HP head torque, 10.4 HP boom power, 40.8 HP sumping thrust. Mucking: Gathering arms - flight conveyor. Haulage: Elevating conveyor-rail cars. Support: Steel sets at 3' or 6', continuous.

MDN STUDY

9/1/72

SYSTEM DATA SHEET
MDN

Ident. No. KM-1
Sheet 2

APPENDIX D

ALGORITHM DEVELOPMENT

In simple regression, it is supposed that with each observation value, there is another quantity which can be observed or somehow related to the observation. After n observations, there exists a series of pairs, (x_1, y_1) , (x_2, y_2) , . . . , (x_n, y_n) . The question we wish to answer is to determine if there is a relationship between y and x and how this relationship can be obtained.

One may assume that there is such a relationship, and that this relationship is linear. With this assumption, one may write

$$y = \alpha x + \beta \quad (1)$$

The x_i , $i = 1, \dots, n$, are the values of the independent variable x , and the y_i , $i = 1, \dots, n$, are the values of the dependent variable y . α and β are the coefficients which will have to be determined from the observation points.

It is possible that a relationship exists between x and y , but the relationship is not linear. A possible alternate in this case is to find another variable, x^l , related to x , such that y can then be linearly related to x^l . The new variable x^l will then be used in place of x in the discussions that follow.

Assuming that the linear relationship is valid, we can create an error term which is the sum of the squares of all deviations of observed values from the linear Equation (1). Thus the error ϵ is

$$\epsilon = \sum_{i=1}^n (y_i - (\alpha x_i + \beta))^2 \quad (2)$$

and determine α and β so ϵ is minimum. This simple regression is known as the method of "least squares". The solution can be shown to be:

$$\alpha = v_{xy} / s_x^2 \quad (3)$$

$$\beta = \bar{y} - \alpha \bar{x} \quad (4)$$

where

$$s_x^2 = \frac{1}{n-1} \sum_{i=1}^n (x_i - \bar{x})^2 \quad (5)$$

$$v_{xy} = \frac{1}{n-1} \sum_{i=1}^n (x_i - \bar{x})(y_i - \bar{y}) \quad (6)$$

\bar{x} and \bar{y} are the arithmetic averages of the x_i and y_i respectively.

Equations (3) and (4) give the necessary coefficients in terms of observed values for the predictor Equation (1). If y had been the MDN, and x an in-situ rock property (or some transformation of it), then this simple regression would have resulted in a predictor equation for the MDN.

A procedure similar to the simple regression technique will be applicable if we want to relate a dependent variable y to several independent variables $x_1, x_2, x_3, \dots, x_{m-1}$. (Note the x_1, x_2, \dots, x_{m-1} are independent variable and not the observation points themselves). If n observations are taken, then one has the following sets of points:

$(y_1, x_{1,1}, x_{2,1}, x_{3,1}, \dots, x_{m-1,1}), (y_2, x_{1,2}, x_{2,2}, x_{3,2}, \dots, x_{m-1,2}), \dots, (y_n, x_{1n}, x_{2n}, x_{3n}, \dots, x_{m-1,n})$.

A linear relationship is assumed to exist between y and $x_1, x_2, \dots, x_{m-1,n}$. Thus, one has

$$y = \alpha_0 + \alpha_1 x_1 + \alpha_2 x_2 + \dots + \alpha_{m-1} x_{m-1} \quad (7)$$

The coefficients $\alpha_0, \alpha_1, \dots, \alpha_{m-1}$ will have to be determined from the n observations of the variables.

To solve for the coefficients requires the manipulation of certain arrays. Defining the following one dimensional arrays:

$$\alpha = \begin{pmatrix} \alpha_0 \\ \alpha_1 \\ \vdots \\ \alpha_{m-1} \end{pmatrix}; \quad w = \begin{pmatrix} y_1 \\ y_2 \\ \vdots \\ y_n \end{pmatrix} \quad (8)$$

Let A be the two-dimensional array.

$$A = \begin{pmatrix} 1 & x_{1,2} & x_{2,1} & \cdots & x_{m-1,1} \\ 1 & x_{1,2} & x_{2,2} & \cdots & x_{m-1,2} \\ \vdots & & & & \vdots \\ 1 & x_{1,n} & x_{2,n} & \cdots & x_{m-1,n} \end{pmatrix} \quad (9)$$

Define a vector error by:

$$z = w - A\alpha \quad (10)$$

The scalar error is:

$$\begin{aligned} \epsilon &= z^T z = [w - A\alpha]^T [w - A\alpha] \\ &= \alpha^T A^T A \alpha - (w^T A \alpha + \alpha^T A^T w) + w^T w \end{aligned} \quad (11)$$

The derivative with respect to α is:

$$\frac{d\epsilon}{d\alpha} = 2A^T A \alpha - 2A^T w \quad (12)$$

For minimum error, $d\epsilon/d\alpha = 0$, thus

$$\alpha = (A^T A)^{-1} A^T w \quad (13)$$

A^T is the transpose of the matrix A given by Equation (9).

The general computational procedure is as follows:

- (1) Form the array A as given by Equation (9).
- (2) Obtain the transpose, A^T , from A . This is just a matter of interchanging rows and columns.
- (3) Compute $A^T A$, then $(A^T A)^{-1}$, then $(A^T A)^{-1} A^T$. This involves a series of matrix multiplications and matrix inversion. These techniques are readily available from a computer.
- (4) Form the array w from Equation (8).

- (5) Multiply the result of Step (3) by the result of Step (4). This yields a set of coefficients $\alpha_0, \alpha_1, \dots, \alpha_{m-1}$.
- (6) Test for goodness of fit or the quality of the predictor equation.

A basic assumption is that the predictor equation is linear, and that the independent variables to use are the observation variables themselves. It may be necessary to define another set of variables $x'_1, x'_2, \dots, x'_{m-1}$ to use in order to obtain a linear relationship.

It often happens that the independent variables are themselves related. If a linear relationship exists between any two of the independent variables, $(A^T A)^{-1}$ will be singular, i.e., $A^T A$ will have zero determinant, and hence $(A^T A)^{-1}$ cannot be computed. If this is so, α is difficult to compute, and the standard errors of the calculated coefficients are huge, giving an inaccurate predictor equation. This problem can be circumvented by performing the regression analysis with one variable, then with two variables, etc. while being careful when this problem arises. One may combine linearly any two variables that are highly correlated and use the combined variable as in the independent variable.

Good computer routines exist which are available on most computers, including routines for matrix transpose, matrix multiplication and matrix inversion, together with standard routines to compute means and standard deviations of a set of observations. In fact, there also exists software that performs stepwise regression analysis, performing the above calculations plus multiple correction coefficients and residuals.

In multiple regression to predict an MDN, the MDN is treated as the dependent variable. The set of independent variables may include the following in situ rock properties.

- (a) Rock classification, quantified, e.g., as Igneous = 1, Metamorphic = 2, Sedimentary = 3
- (b) Compressive strength, Fc
- (c) Rock quality designation, RQD
- (d) Dry Unit Weight, DUW
- (e) Hardness, H
- (f) Ground Water, GW quantified, e.g., as Dry = 1, Minor = 2, Wet = 3

Additional parameters peculiar to the excavation method may also be included in the set of independent variables. Some of these variables may be excluded from the analysis; others still undefined may be included. The regression analysis may be performed using one or more of these variables.

A set of observations is obtained, and with each set of observations, an MDN is indicated. A table with the following entries will be created:

<u>MDN</u>	<u>CLASS</u>	<u>Fc</u>	<u>RQD</u>	<u>DUW</u>	<u>H</u>	<u>GW</u>

It is seen that y corresponds to MDN, and CLASS, Fc, RQD, DUW, H, and GW, correspond to x_1, x_2, \dots, x_3 , respectively. The matrix in Equation (9) corresponds to the observation points. The array in Equation (8) corresponds to the MDN indicated in column 1. The predictor equation may be obtained from Equation (13).

Several iterations of this analysis should be performed on the computer in order to determine which variable or combinations of variables are appropriate to include in the predictor equation. Certain tests can be performed to determine the quality and accuracy of this predictor equation. With computer routines readily available, several iterations may be performed with reasonable cost and in a very short time.

APPENDIX E

TRANSPORT SYSTEM SELECTION PARAMETERS

The following list of equipment capabilities, system constraints, and MDN applications is taken in part from Report No. FRA-RT-71-57, "Materials Handling for Tunnels," HN-8080, Holmes & Narver, Inc., and Resource Management Corporation, September 1970, prepared for the U. S. Department of Transportation, Washington, D. C., with additional details provided by the authors. With some differences, the list was incorporated as Section 3.6 of the Annual Technical Report of the first year's program. MDN applicability is based only on muck characteristics, and is subject to constraints imposed by such factors as tunnel size, grade and length, equipment and power cost and availability, and environmental considerations.

UNITIZED SYSTEMS

Conventional Rail Systems

Capabilities and Advantages

- Hauling capacities can be varied by the addition or removal of cars or trains.
- Materials, supplies, and personnel can be transported by the system.
- Easily adaptable to automatically controlled operation.
- Loading and dumping can be done rapidly.
- Track extension is relatively simple.

System Constraints

- A large percentage of tunnel cross section is occupied by equipment.
- High speeds needed for short cycle time.
- Ideal road bed and track conditions are necessary if delays cannot be tolerated.
- Passing tracks are required in long tunnels.
- A secondary system or assisted haulage is needed if vertical grade is over 4 percent.
- Supply of materials required for system extension is a major operation at high advance rates.

Small clearances, high speeds, and massive moving equipment combine to produce long delays and serious injuries in event of accidents.

Combustion products complicate ventilation unless vehicles are powered electrically.

Applicability

Applicable to any of the MDN's so far developed. Special cars would be required for high speed operations with very wet muck, and special dumping facilities with MDN's 6 and 7.

Siderail Systems

Capabilities and Advantages

Hauling capacities can be varied by the addition or removal of units.

Materials, supplies, and personnel can be transported by the system.

Automatically controlled operation.

Loading and dumping can be done rapidly.

Can be used on much steeper grades than conventional rail systems.

Vertical and horizontal guidance tends to reduce frequency of derails and other accidents.

System Constraints

Power units for siderail systems require electrical bus bars to be extended with the track.

The small size of units in current use limits haulage capacity, and the number of power units can result in maintenance problems and delays.

Continuous bus bars may be a personnel hazard.

Applicability

MDN's 1 through 7 could be transported by this system. Problems in unloading cars can be expected from MDN's 6 and 7 if wet, due to the high percentage of fines.

Free Vehicles

Capabilities and Advantages

System capacity can be varied by the number of vehicles or by change in speed.

Materials can be transported inbound and outbound.

Guideway for operation is not required.

System Constraints

Tunnel size limits use of free vehicles in small tunnels unless turnouts are provided.

Roadway must be well graded and maintained to support weight and speed of vehicles.

Present design of vehicles uses excessive amounts of tunnel volume per ton of capacity and does not provide the ability to operate in both directions equally well.

Inability to climb grades of 8 to 12 percent at adequate speeds.

Operator required for each vehicle.

Small clearances, high speeds, and massive equipment combine to produce long delays in case of malfunction, and serious injuries in event of accident.

Combustion products complicate ventilation unless vehicles are powered electrically.

Applicability

MDN's 1 through 5 can be transported by free vehicles. Excessive tire wear could be expected in the MDN 1 and 2 range due to angularity and abrasiveness of these materials. This system may not be practical for sites producing muck in the MDN 6 and 7 range because of traction and roadbed maintenance problems.

SEMICONTINUOUS SYSTEMS

Belt Conveyors

Capabilities and Advantages

Possible installation overhead or at sides of tunnel leaves floor space for other uses.

Capacities can be increased by changing belt speed.

Conveyors can go up or down slopes to 22 degrees.

System Constraints

Supplementary transportation which must be provided for incoming materials and personnel.

Delays inherent as the conveyor is extended from a temporary to a semipermanent installation.

Applicability

All MDN's can be transported by conveyors. Excessive belt damage and wear can be expected in the MDN 1 and 2 range because of piece size and shape unless the material is crushed prior to being placed in the system. In the MDN 6 to 7 range, through a wide range of water occurrence, considerable material will stick to the belt causing excessive cleaning problems. In the entire MDN range it is mandatory that the water content be below the point where the muck will slip or flow on the belt or overflow the sides.

Hydraulic Pipelines

Capabilities and Advantages

Capacities adequate for the tonnage from any tunnel in the foreseeable future.

Pipelines use very little space in the tunnel.

Especially adaptable to very wet sites and to hydraulic excavation systems.

Adaptable to any grade, including vertical.

System Constraints

Capacity to handle plus 1-inch to plus 2-inch material through centrifugal pumps has not been demonstrated in field usage. Crushing or scalping equipment for through-centrifugal pump systems, or lock-feed equipment for alternate designs may cause congestion in the near face area.

Large amounts of water are required.

Required electrical power may be difficult to provide for long tunnels in remote areas.

Dewatering, recirculation, and muck disposal systems may be elaborate.

For high advance rates, methods of advancing pumping units and pipelines must be developed.

The heat load from large electrical installations may be difficult to dissipate.

System malfunctions may be hazardous to personnel.

Applicability

MDN 7 is best suited for pumping because of the low percentage of plus #4 material and a high fines content. Preliminary screening and/or crushing would be needed for transporting all MDN's by a through-centrifugal pump system.

Pneumatic Pipeline

Capabilities and Advantages

Pipelines use very little space in the tunnel.
Adaptable to any grade, including vertical.

System Constraints

Power requirements appear excessive.
Muck must be relatively dry.
Crushing or scalping equipment must be used if pieces are too large for system.
Pipe wear and maintenance may be excessive.
Secondary transportation must be provided for materials and personnel.
Methods of advancing blower units and pipe must be developed.
Dust at the discharge or from malfunctions may be hazardous to personnel.

Applicability

MDN 7 is best suited for pneumatic systems because of the low percentage of plus #4 material and the high fines content. Preliminary screening and/or crushing would be needed for transporting all MDN's.